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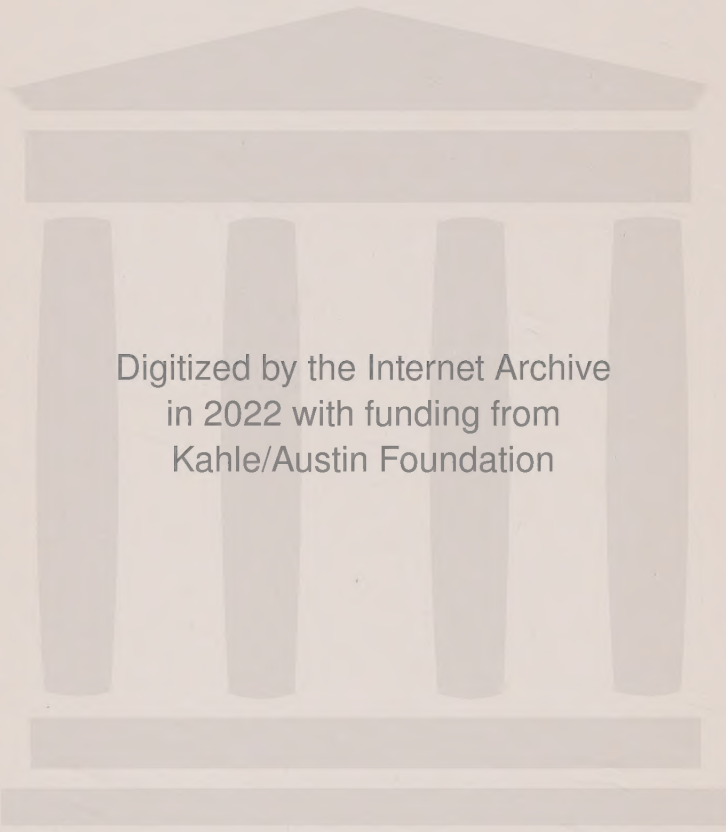
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ALUMINUM BRONZE POWDER
AND
ALUMINUM PAINT

BY
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Chapter I.

Manufacture of Aluminum Bronze Powder.

The bronze powder art was originally an offshoot of the goldbeater's art. The goldbeater learned to hammer sheets almost unbelievably thin,—only a few millionths of an inch in thickness. This was accomplished by interleaving sheets of gold foil with goldbeaters' skin and beating the pack with a heavy hammer until the requisite thickness of gold leaf was produced. This gold leaf could then be cut or shredded into minute pieces so as to make a flake-like powder,—the scraps served excellently for the purpose. The shredding was done by rubbing the gold leaf through a fine mesh wire sieve. Naturally, such a powder was very expensive and the production necessarily limited. However, the metallurgist in time developed base metal alloys that duplicated the color of gold very satisfactorily; in fact, the metallurgist supplied alloys that could be given almost every tint of the rainbow. Human ingenuity then devised mechanical means to replace the tedious manual methods of the goldbeater, and the modern bronze powder art was born about the middle of the nineteenth century.

The story is told that Sir Henry Bessemer was so impressed with the potential profit in the sale at about twenty-five dollars per pound of gold bronze powder made from brass that he devoted himself to the problem of its manufacture.¹ The obvious method of attack was to substitute mechanical means for the laborious hand work of the goldbeater. It was not so difficult to reduce metal to fine particles, but to give them the form, color and luster of the bronze powders on the market was a problem for which he did not readily find the solution. However, after several years' experimentation he was successful. By keeping his process secret, he dominated the market for many years to his own substantial

¹ Smalley. *The Metal Industry* (London). Vol. 24, p. 273 (1924).

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profit. His methods were the forerunners of the processes in use today.

The name "bronze powder" undoubtedly came from the copper alloys first used in the production of these metallic powders. By alloying and by heat treating, bronze powders of wonderful beauty and color were produced, but silver and tin were about the only available metals which would give a "silver bronze powder." Silver was expensive, and tin did not readily adapt itself to current manufacturing methods.

By the end of the nineteenth century aluminum had become commercially available for the production of metallic powders of silvery hue. Although not made from a bronze alloy, nevertheless, custom dubbed it "aluminum bronze powder," and aluminum bronze powder it still is. The name is sometimes misleading to metallurgists not familiar with the bronze powder art, since they have given the name "aluminum bronze," to a copper-aluminum alloy (10 per cent aluminum) of beautiful golden color. As a matter of fact, the alloy aluminum bronze is sometimes used for the manufacture of a very high grade gold bronze powder. However, some distinction must be made between the lustrous aluminum bronze powder and the utterly different, dull and sometimes gray to black aluminum powders made by various atomization and pulverization methods. Perhaps, therefore, continuation of the name, "aluminum bronze" powder is justified, in order to definitely align it with the proper art. Although aluminum bronze powder is the newest of the metallic bronze powders, it has proven so useful that it has now become the most important of the group.

Manufacture of Bronze Powder.

There seems to be but one way to make metallic bronze powders, no matter what the specific mechanical arrangement employed. By pressure, the metal must be forced to "flow" into flake-like particles. Pressure, such as in stamping, produces a burnishing action and enhances and conserves metallic luster and brilliancy. Abrasion and grinding produce a reduction in size of particle, but the powder so produced is dark in color and granular in nature. It is almost totally lacking in the brilliant flakes which give bronze powders their characteristic appearance and value. Abrasion and grinding action must therefore be reduced to a minimum.

The manufacture of aluminum bronze powder resolves itself into a process of hammering aluminum under mechanical stamps until the particles are small enough and thin enough for the desired purpose. As a raw material, aluminum of a fairly pure grade is desirable. The best grades of powder are made from aluminum running 99 per cent or better in purity. If iron and silicon are present in excessive amounts, they render the metal hard and difficult to stamp into thin flakes. Furthermore, they form constituents in the aluminum which are blue to gray in color, and tend to detract from the natural silvery hue of aluminum.

Since sheet aluminum is well on the way to foil and flake, it provides, when available, a convenient material with which to start the stamping operation. It is cut into small and uniform pieces and reduced to as uniformly soft and ductile condition as possible by annealing. It is essential that the aluminum be free from grease, dirt, pieces of iron and other substances which will give a powder which is gray in color and of inferior quality. For this reason scrap aluminum can only be used if it is strictly clean and free from such contamination.

Stamping Operation.

The stamps are of various design, according to the particular ideas of the maker and user. In general, though, they consist of a series of steel hammers raised by cam action and allowed to fall on a steel anvil or mortar, which is suitably enclosed. These stamps are customarily arranged and operated in banks. The small pieces of aluminum sheet are first placed under heavy duty stamps, where the reduction to flake begins. In order to keep the pieces of aluminum from welding together, a very small amount of lubricant is used to coat the metal pieces during the stamping operation. The use of a suitable lubricant is also said to facilitate the breaking up of the large flakes into smaller flakes as the stamping proceeds. Various lubricants have been employed, such as tallow, stearic acid, olive oil, rape oil, etc.; mineral oils are unsatisfactory for this purpose. As the stamping proceeds, the continual cold working not only beats out the aluminum into foil-like sheets, but also hardens and embrittles the metal so that it readily breaks up into smaller and smaller flakes. At a suitable point the flake-like material is transferred

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to lighter stamps better adapted to hammer it out into the thin particles which are to constitute the final product. The "tailings" or over-size particles are returned for further stamping. The total time of stamping will obviously depend upon the size of the original pieces of aluminum, and the force and number of blows delivered by the stamps. It usually takes many hours and is a time-consuming operation, requiring skillful attention for its proper execution.

The product of the stamps is separated into various grades by sifting operations. Wire sieves and silk bolting cloth are commonly employed in the sifting operation, although air separation is suitable for the handling of the finer particles. The appearance of the powder is largely influenced by the relative proportions of large and small flakes. The grading of the powder will be discussed in some detail in the following chapters.

Polishing.

Most grades of aluminum bronze powder are submitted to a final operation known as polishing. The conventional type of apparatus for polishing is a cylindrical drum with a series of revolving brushes bearing lightly against the inner surface. The powder is placed in the drum with a small addition of lubricant, and the brushes revolved. The polishing smooths out the flakes by causing them to rub against each other and against the cylinder and brushes. During the process, each flake is also coated with an extremely thin film of lubricant, which confers upon the flakes the power of leafing, a property which will be discussed later. Stearic acid is the usual lubricant employed at this stage, although manufacturers, by experiment, have developed a variety of useful compositions for this purpose.

When the polishing operation is complete, the powder is ready for packing. During the first few weeks thereafter, some change appears to take place between the metal flake and the film of lubricant, which tends to arrange and "fix" the film upon the flake; this materially improves the appearance and quality of the powder. The leafing power of the powder develops during this period. The powder is then ready for use.

The manufacture of aluminum bronze powder, as well as other types of bronze powder, has been described in detail by Oliver

Smalley in a series of articles in *The Metal Industry*.² Otto Von Schlenck³ has also published a discussion of bronze powder in *Metal Industry* (New York). For a description of the machines employed and further details of their operation, the reader may consult these articles.

Powdered or Atomized Aluminum.

Another form of finely divided aluminum is known as atomized aluminum, or sometimes just powdered aluminum. It is made by disintegrating a stream of molten aluminum with a blast of steam or air. The molten aluminum is blown into very fine particles more or less spherical in shape; the product is usually dark gray in color with much the same appearance as zinc dust.

It has sometimes been supplied on orders which called for "aluminum powder," and which did not make it clear that aluminum bronze powder was required. Atomized aluminum is not a suitable material for the production of aluminum paint.

Grained Aluminum.

If molten aluminum is stirred slowly while it is solidifying, it breaks up into fine grains because it is "hot short" at temperatures not too far below the melting point.⁴ The product made in this way is known as "grained" aluminum. The particles are rough, irregular shaped grains which vary in size from about 1/64th inch to grains about 1/8th to 1/4th inch in width or length. This material would not be mistaken for atomized aluminum or aluminum bronze powder. One of its important uses is in the Thermit reaction.

Granulated Aluminum.

Granulated aluminum is made by pouring molten aluminum through a vibrating iron sieve and allowing the particles of molten metal to fall into water. The particles formed in this way are flattened drops of aluminum and vary in size up to about 1/2 inch in diameter. It is used almost exclusively in the deoxidation of steel.

² Smalley. *The Manufacture of High Grade Aluminum and Bronze Powders*. *The Metal Industry* (London). Vol. 24, pp. 273, 296, 445, 493, 569 (1924). Vol. 25, pp. 169, 369 (1924). Vol. 27, pp. 1, 93, 185, 283, 575 (1925).

³ Von Schlenck. *Metal Industry* (New York). Vol. 15, pp. 77, 161, 200, 298 (1917).

⁴ Von Schlenck. *Metal Industry*. Vol. 15, p. 78 (1917).

Chapter 2.

Properties of Aluminum Bronze Powder.

Microscopic Appearance.

The flake-like character of aluminum bronze powder is quite apparent upon close visual examination. It is especially well shown, however, by examination under the microscope. Figure 1 is a photomicrograph of several flakes of aluminum bronze powder taken at a magnification of 500 diameters with reflected light. The somewhat irregular shape of the flakes is only what would be expected from the nature of the stamping process. In the photomicrograph the flakes appear lined with irregular dark markings. These are fine "wrinkles" and indentations in the surface of the flake, which result from having been stamped in contact with many other flakes; under the vertical illumination of the microscope they reflect no light through the eye-piece and hence appear as dark lines. This wrinkled surface is no disadvantage, however, since it can only add a slight diffusing effect to light reflected from it. In general, the polished flakes are remarkably flat, as can be judged from the fairly good focus obtained over the whole surface.

Figure 2 shows a photomicrograph of powder taken by transmitted light at a magnification of 100 diameters. The flakes appear in silhouette and their characteristic shape is very apparent.

The thickness of flake is a point of interest, likewise a difficult value to determine accurately. The individual flakes obviously exist in a wide range of widths or diameters, and considerable variation may be expected in the thickness of flake. An estimate of the average thickness of various powders has been made in the following way: A weighed amount of powder (0.1 gram) is carefully dusted onto the surface of some water held in a rectangular pan. The powder, not being wet by the water, remains on the surface and spreads out to a mirror-like film if the operation has been skillfully done. The surface is not completely covered, but if a strip

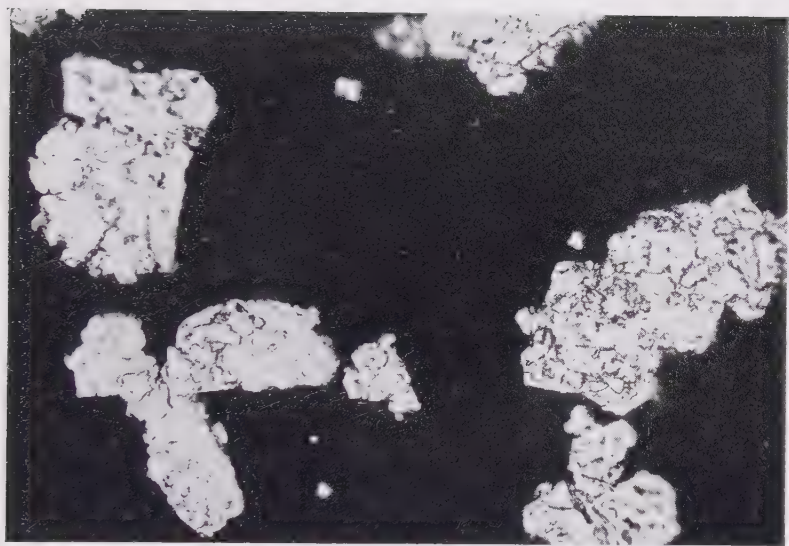


FIG. 1.—Aluminum Bronze Powder at 500 diameters; photographed with reflected light.

of paraffined paper is started at one side and moved along the surface, it compresses the film into rectangular shape and largely fills up the voids. The area occupied by the film is reduced until the film just begins to wrinkle; at this point, if conditions are ideal, the flakes are all lying flat on the surface and touching each other. Knowing the volume of powder and the area, the thickness can be calculated. One such measurement gave a value of 0.00017 cm or 0.00007 inch. If a substantial number of flakes lie on top of each other, the observed thickness would be too great. On the other hand, because of the irregular shape of the particles, there are "holes" between flakes which would tend to make the observed values too small. When measured in this way, not much difference was observed in the thickness of flake of domestic and foreign powders of similar grade. Von Schlenck ³ gives the figures 0.00001 inch to 0.00002 inch for the thickness of flake without any information as to the method of measurement. Smalley ² says that the ratio of width to thickness may be as high as 200 to 1, or as low as 5 to 1 in very poor powders. The practical point in this connection is that with flakes of a given area, the thinner they are, the greater the number of flakes per unit weight.

Density.

The density of pure aluminum is very close to 2.700 grams per cc. Aluminum bronze powder has, however, a substantially lower density because of the lubricant and oxide film on each particle. Density values for the powder are only approximate, but one measurement gave the figure 2.1 gram per cc. About all that can be said is that the density usually lies within the range 2.0 to 2.7. Aluminum bronze powder is so "fluffy" that the apparent density is substantially lower; it depends to a large extent, of course, on the amount of settling or packing which the powder has undergone. If powder is scooped up with a minimum of settling or tapping, the apparent density may be as low as 0.7 or even lower. Two pounds of powder, the amount commonly used per gallon in making aluminum paint, will occupy about 72 cubic inches under the mythical "average" conditions of settling.

³ See reference 3 on page 13.

² See reference 2 on page 13.

Grades.

The system of grading and classification of powders varies according to the individual manufacturer. The practice of Aluminum Company of America is to designate powders for use in paint and lacquer as "varnish" powders, for example, "Standard Varnish." The various grades are further distinguished by their characteristic distribution of particle sizes; they are known as Extra Brilliant Varnish, Standard Varnish, and Extra Fine Varnish.

The largest flakes in Extra Brilliant powder are larger than the largest ones in Standard Varnish Powder. Similarly, the largest flakes in Standard Varnish powder are larger than those in the Extra Fine grade. The average or characteristic particle size, therefore, appears to decrease in the same order.

A partial screen analysis of Standard Varnish powder, for example, might show a distribution of particle size somewhat as follows:

TABLE 1.
SCREEN ANALYSIS OF TYPICAL ALUMINUM BRONZE POWDER.

Mesh Size	Per cent
On 150 mesh.....	0.6
Thru 150 mesh and on 200 mesh.....	12.8
Thru 200 mesh.....	85.0

To a great extent the appearance of a powder is modified by the size of the largest particles present, even though they are present in relatively small proportion. The larger particles have, obviously, a larger reflecting area, and give a marked brilliance to the powder. The small particles are essential, however, in giving continuity to the leafed surface and durability to the paint film.

A series of powders is made for use in printing inks, sign painting, decorating and similar purposes. These are finer than the Varnish powders and are called Lining powders; their names are Standard Lining, Extra Fine Lining and Superior Lining.

In addition to the Varnish and Lining powders, other grades are known as "Litho" powders. The Litho powders are used for printing and decorating processes in which the powder is dusted on and adheres to the inked impression. The excess powder is

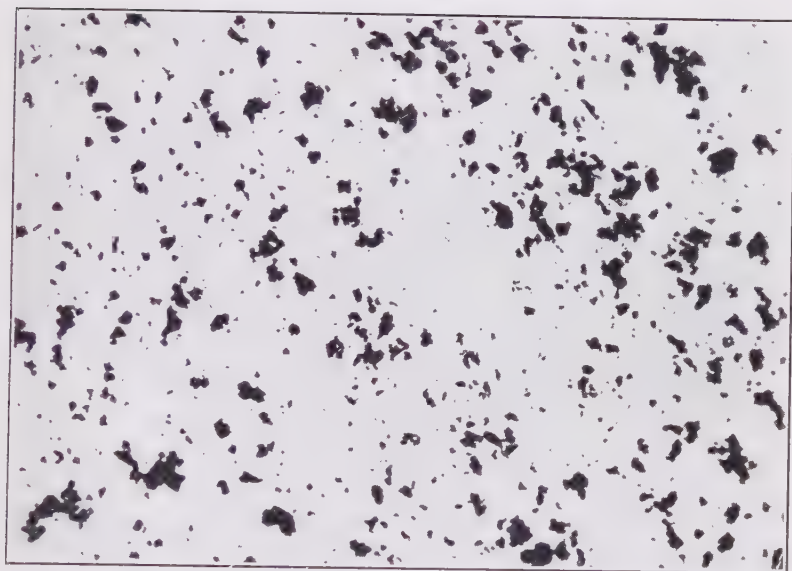


FIG. 2.—Aluminum Bronze Powder at 100 diameters; photographed with transmitted light.

blown or brushed off, and it is essential that it be readily removed without staining the surface. Litho powders are therefore polished with a minimum of polishing medium. Extra Brilliant Litho, Standard Litho and Extra Fine Litho are the regular grades, with particle size corresponding to the varnish powders previously mentioned.

Unpolished powder is also used for special purposes. Another special grade, known as "Flitter" is very coarse, (thru 18 mesh) and is used largely for decorative purposes and fireworks.

Leafing.

One of the most useful and characteristic properties of aluminum bronze powder is its ability to leaf in certain liquids. The powder, when stirred in a vehicle like oil or varnish, for example, swirls around and part of the particles come into the surface layer, where they remain to form a continuous metallic film. The aluminum flakes are specifically heavier than the liquid, yet the effect of particle shape and the surface tension forces between flake and liquid are sufficiently great to hold them at the surface in spite of the difference in density. The term "leafing" is very descriptive of the phenomenon, since the flakes in the surface film are arranged much like falling leaves.

The formation of a leafed film of aluminum bronze powder can be readily followed in detail under the microscope and is a very interesting phenomenon. After considerable experimentation, Mr. Louis Isaacs, of the Motion Picture Producing Company, succeeded in recording a moving picture of the process. Aluminum bronze powder, suspended in a black vehicle, to give photographic contrast, was placed on a microscope slide and photographed at a magnification of about 10 diameters. Because of the magnification employed, the short exposure, and the very small distance from paint film to lens, the illumination problem was a very difficult one. Part of the film is reproduced as Figure 3. The first frame shows the paint immediately after stirring of it had been discontinued. The first eight frames represent the first half-second, since the exposures were made at the rate of sixteen per second. The rapid motion of the particles at the start is shown by the slightly blurred and elongated shape of many of the flakes. The powder leafed very rapidly in this mixture and the leafing was

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about 90 per cent complete in one second. The next frames shown are the 12th and 16th; from this point on, only every eighth successive frame is reproduced, and each frame represents an additional time interval of 0.5 second. The last few small holes in the paint film filled up slowly but surely, so that after about six seconds leafing was complete.

The ability to leaf is determined by the properties of both the powder and the liquid. Unpolished powder, practically speaking, will not leaf in oil or varnish. The film of polishing agent placed on each particle during the polishing process is what confers this property. A rough estimate shows that this film may vary in thickness from a layer a few molecules deep to a layer 15 or 20 molecules deep, depending on the amount of polishing medium used. It seems probable that the molecules in the outer surface layer are specially oriented and that this orientation is important in determining certain of the leafing characteristics. Naturally, the kind of polishing medium employed, as well as a variety of other factors, influences the final results; some of these will be discussed later.

Some vehicles and volatile thinners promote ready leafing, while others are poor or indifferent in their action. There is a significant relation between the "leafing power" and surface tension of liquids. The leafing power of a powder may also deteriorate or entirely vanish as the result of long-continued contact with a liquid or paint vehicle. This fact presents quite a problem in the manufacture of ready-mixed aluminum paints.

Handling Aluminum Bronze Powder.

In handling and using aluminum bronze powder, it must not be forgotten that it is a "combustible dust" in the same sense as starch, flour, powdered coal, etc. The heat of combustion of aluminum to form aluminum oxide is high, and aluminum powder suspended in sufficient concentration in air will constitute a potentially explosive mixture. Care should be taken, therefore, to prevent the accumulation of the dust in locations where it is being continually used. Naturally, flame and electric sparks should also be avoided in places where aluminum powder may be in the air or be readily stirred up. These precautions are particularly to be observed in operations like lithographing and bronzing, where the powder may

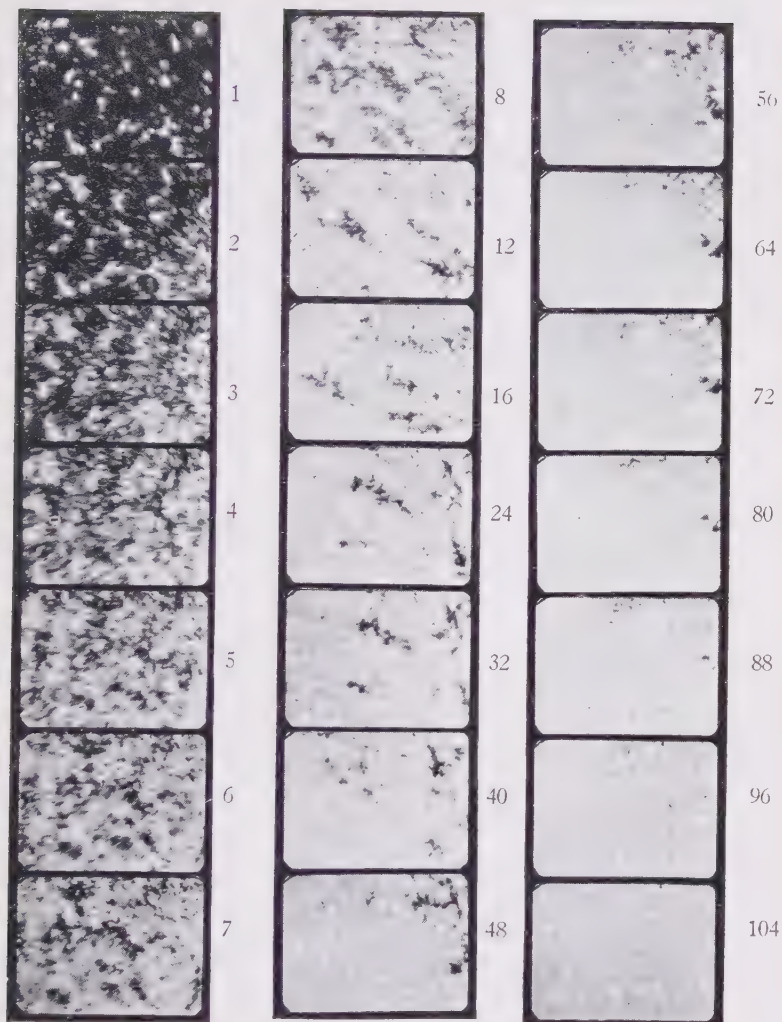


FIG. 3.—Motion picture of process of leafing of aluminum bronze powder in paint film; the number beside each frame indicates its order number in the original negative as explained in the text.

be used in dusting operations without liquid. When the powder is mixed with vehicle, as in aluminum paint, it constitutes no special hazard.⁵

In storing aluminum bronze powder in quantity, the following precautions are to be observed: Keep the powder dry; in contact with water it may slowly react and heat as a result. In case of fire, *do not put water on aluminum bronze powder*. Smother the fire with sand without disturbing any powder which may be burning. Keep the premises clean and free from accumulations of aluminum bronze powder as "dust" on ledges and other horizontal surfaces. With intelligent handling, the hazard in using aluminum bronze powder is less, for example, than in handling the volatile thinners of the paint trade. Since, however, emergencies do sometimes arise, it is well to know how to care for them.

⁵ See also "The Inflammability of Aluminum Dust," by Alan Leighton, Bureau of Mines Technical Paper No. 152, January, 1919.

Chapter 3.

Examination of Aluminum Bronze Powder.

Qualitative Tests.

For many if not most uses the value of aluminum bronze powder depends on its appearance; or more exactly, its appearance after application. For this reason the human eye has been the most generally useful tool in examining and testing powder. The eye, however, has its limitations, and furthermore, provides no quantitative record of its observations. Further development in the testing of aluminum bronze powder is necessary before it can be said to have been placed on a satisfactory scientific basis.

About the simplest test which can be made is to dip the tip of one's finger in the powder and then transfer some of this powder to a fingernail on the other hand. If two powders are to be compared, another finger may be employed to transfer some of the second powder to the fingernail next to the first one. The powder may also be "striped" on the palm of the hand instead of the fingernail. The principal points to be noted in examining the streaks of powder are the relative sizes and proportionate number of flakes. Some idea of differences in color and brilliancy may also be obtained in this way. While a person by practice may become very skilful in such examination, the method has many limitations—and frequently leads to mistaken conclusions.

A somewhat more elaborate test is known as the striping test. A sample of powder is measured out and mixed with a standard volume of test liquid, usually a varnish. A soft camel's hair brush is then filled with the mixed paint and applied in a single brushing stroke to a sheet of white glazed paper. Usually a second stripe is applied just below the first, using the paint left on the brush after the painting of the first stripe. The ease and completeness of leafing of the powder can be readily observed in the first stripe; particularly at the beginning, where the paint film is thickest. In

this way a series of powders, made into paint, can be compared for differences in leaing, color, reflectivity and particle size. It should be remembered, however, that this method of examination is as much a test of the vehicle as of the powder, and the results will vary with different vehicles. In order to make the comparison of value, the test conditions should be kept strictly comparable—a condition which is not readily maintained. Much can be learned, however, by skilful and intelligent application of such tests.

Chemical Analysis.

In a quantitative way, composition is one characteristic which can be determined with considerable accuracy. The aluminum employed in the manufacture of bronze powder ordinarily contains iron, silicon and copper as impurities. In particular, the iron and silicon form constituents in aluminum which are blue to gray in color; they give commercial aluminum its bluish tinge. If present in excessive amounts, they will injure the color of the powder. Powder of the best grade is made from aluminum containing less than about one per cent of metallic impurity. A powder may also be off color as a result of contamination with "dirt" of some kind, so that a specification regarding purity of the metal used in powder making will not necessarily insure the securing of a powder of satisfactory color. Unfortunately, (or perhaps fortunately, as you may view the matter) the eye is a better judge of fine differences in color than chemical analysis. Where chemical analysis is desired, the Tentative Methods of Chemical Analysis of Aluminum of the American Society of Testing Materials should be employed.*

Chemical analysis is useful in detecting the presence of adulterants which cheapen the powder and injure its usefulness. Mica is the most common adulterant employed. Its presence is very difficult to detect visually because of the high reflectivity, at certain angles, of the flake-like mica particles. They are injurious to the protective value of a paint because they are transparent to light. Mica is a complex aluminum silicate, commonly containing magnesium. Its presence can usually be detected by treating a small portions of the powder with dilute hydrochloric acid (1 to 5) with gentle heating until gas evolution ceases. The aluminum

*A. S. T. M. Tentative Standards, 1926; Serial Designation B40-26T (p. 219).

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will dissolve, while any mica present will be practically insoluble under this treatment and remain as a white residue which can be filtered off and examined. Generally, mica can be recognized by its flake-like form, especially if examined under the microscope at low power magnification.

An attempt is sometimes made to determine the amount of polishing medium (tallow, stearic acid, etc.), on the powder by the usual chemical methods. A weighed sample is placed in an extraction thimble and extracted with a solvent, such as acetone or ether.

Ordinarily the portion soluble in acetone is less than that soluble in ether, but neither represents the total amount present. When stearic acid has been employed in polishing, it is reasonably probable that it has reacted in part with the aluminum or aluminum oxide to form aluminum stearate, which is less soluble than the stearic acid. The presence of an excessive amount of stearic acid on a powder is generally disclosed by a greasy feeling and appearance. Except for comparison and research purposes, it is questionable whether the determination of the acetone extract gives information of sufficient value to warrant making the test. The acetone extract of a series of powders, domestic and foreign, was found to be between about 0.5 and 3 per cent.

Although a powder may be made from aluminum having a purity of 99 per cent, it will not contain 99 per cent metallic aluminum. Aside from the per cent or so of lubricant, the powder will contain aluminum oxide, resulting from the surface oxidation of the flakes during the stamping process. The oxide so formed may readily amount to several per cent.

The oxide content can be determined in several different ways. One method, which may be called the oxidation method, is to put into solution a weighed sample previously freed from grease; then precipitate the metal as hydroxide, and finally ignite and weigh as oxide. From the increase in weight, as the result of converting aluminum to aluminum oxide, the content of metallic aluminum can be calculated. Another method is to dissolve the sample in potassium hydroxide; the evolved hydrogen is passed through a combustion train and collected and weighed as water. The hydrogen evolved and the metallic aluminum equivalent can then be

calculated. In both of these methods, the oxide is determined by difference.

Leafing Tests.

It is common observation that the speed and completeness of leafing will vary with different powders as well as different vehicles. Some quantitative measure of these variables is very useful in comparing different powders, vehicles and paints. A qualitative observation can be obtained from the striping test previously discussed. A quantitative method, which seems to have interesting possibilities, is also being developed in the author's laboratories.

If a steel spatula is dipped into aluminum paint and then suspended to allow the excess paint to drain off, leafing of the powder in the paint film begins almost immediately. Leafing takes place most readily at the bottom end of the spatula, where the paint film is thickest, and gradually extends up the spatula with a speed and completeness depending upon the "leafing power" of the paint. If leafing is not complete, there will be a certain level on the spatula above which there will be obvious cracks and "breaks" in the leafed film. If the spatula was immersed to a depth of 10 cm and, after a suitable time interval, the paint film has perfectly leafed to a height of 6 cm, then the paint may be said to have a leafing power of 60 per cent.

By standardizing the conditions of test, a useful method is provided. When testing powders, a standard vehicle is necessary, and when testing vehicles, a standard powder is necessary. For a standard test vehicle there may be used a solution of 30 grams of powdered cumar resin in 100 cc mineral spirits meeting Federal Specification No. 16. This liquid was chosen because it does not allow any powder to leaf 100 per cent in this test as do many good varnish or oil vehicles and hence a comparison of different powders may be obtained by its use. The steel spatula employed has a length of $5\frac{1}{2}$ inches and a width between $\frac{1}{2}$ and $\frac{9}{16}$ inch. In making the test, 25 cc of the vehicle is thoroughly mixed with 4 grams of the aluminum powder to be tested. The test tube (6" long x $\frac{5}{8}$ " I.D.) is filled with the paint to a depth of $4\frac{1}{2}$ inches. The temperature of the paint is held between 20 and 25°C, and the surrounding air temperature should be between 20 and 30°C. The

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test tube is closed with a cork and inverted or stirred in order to secure a uniform suspension of the powder in the liquid. The spatula is then dipped into the mixed paint until it touches the bottom of the tube. After allowing it to remain for 5 to 10 seconds, the spatula is withdrawn and suspended vertically in free space for about two minutes. In some cases leafing may be slow and a longer time interval may be selected. The height of the perfectly leafed area is then measured and expressed as a percentage of the total depth of immersion of the spatula.

If a mixed paint is to be tested, obviously the standard test liquid is not needed. The standard test liquid as described above gives results comparable with those obtained with some of the vehicles now used for aluminum paint. However most good vehicles promote substantially better leafing of aluminum bronze powder than does this test liquid. Except for standardizing the technique and test conditions, the method is not original with the Aluminum Company of America, and is only put forward as an experimental method. It is subject to development, and more experience must be gained with it before a full interpretation of test results is possible. For those interested in experimental work along these lines, the method may prove a useful tool.

Screening Tests.

A good approximate idea of the distribution of particle sizes in a powder can be obtained by passing the powder through a series of standard screens. Usually no attempt is made to further classify the material passing through the 200 mesh screen. In making such tests, it is very desirable to use a standardized technique. The standard screens containing a 30 gram sample of powder, properly assembled and covered, should be held in some mechanical tapping device and shaken for a suitable period. A test for completion of screening should be applied; the technique of this has been described in detail in Bureau of Standards Technologic Paper No. 42 by R. J. Wig and J. C. Pearson, entitled "Standardization of No. 200 Cement Sieves." The effective mesh opening of a screen is larger for a thin flake than for approximately spherical particles like cement grains. A very thorough cleaning of the sieve may be accomplished by



FIG. 4.—Equipment for measuring leafing power of aluminum paint.

dipping it in acetone; the adhering powder floats out of the gauze and can be skimmed off.

A difficulty met with in the screening of bronze powder is the aggregation or sticking together of flakes. For example, a powder which all passed through a 140 mesh screen during the process of manufacture may still show, on test, several tenths of a per cent of powder retained on a 100 mesh screen. By the use of a liquid, such as acetone or gasoline, most of this remainder may be put through the screen. The preferred practice however, is that described in the preceding paragraph where no liquid is employed except to clean the sieve after the test is completed.

Reflectivity.

The reflectivity of aluminum paint films can be measured with satisfactory precision by means of the Taylor reflectometer, which was developed at the Bureau of Standards.⁷ The photometric measurement is made with a Macbeth illuminometer attached to the reflectometer. This method measures the total or diffuse reflecting power of the surface under examination. It requires a test piece three or four inches square for measurement; the necessary observations can be made in five to ten minutes.

⁷ A. H. Taylor. Bureau of Standards Scientific Paper No. 405, 1920.

Chapter 4.

Aluminum Paint.

Aluminum bronze powder is a unique paint pigment. When mixed with a suitable oil or varnish vehicle, it forms a paint having an unusually serviceable combination of properties such as high opacity, high reflectivity, low emissivity, high moisture-proofing efficiency and great durability. Unlike most other pigments, aluminum bronze powder does not need to be ground in oil, and in fact is injured by grinding. Simple stirring of the pigment into the vehicle to form a uniform suspension is all that is required to prepare the paint for use. It can then be applied like other paints, either by brushing or spraying. With a suitably chosen vehicle, it can be applied generally on metal, wood, cement and concrete, brick, stone, etc., and is remarkable for the many specific applications which it has.

Compared with many paints, the use of aluminum paint is a strictly modern development. Although aluminum bronze powder has been available for the past 25 to 50 years, its extensive industrial application is a development of the last ten years. Aluminum paint spent its infancy, so to speak, in decorating picture frames and radiators. That it had a larger industrial use was not appreciated until research had determined the proper composition for use for various purposes and established its resistance to weathering, as well as its other valuable properties.

Early Tests.

Probably the first extensive test of aluminum paint to be made in this country was carried out at the Institute of Paint and Varnish Research in Washington under the direction of H. A. Gardner. Some 58 panels carrying aluminum paint in one or more coats, and six comparison panels with red lead, blue lead, zinc powder, etc., were exposed at Washington in October,

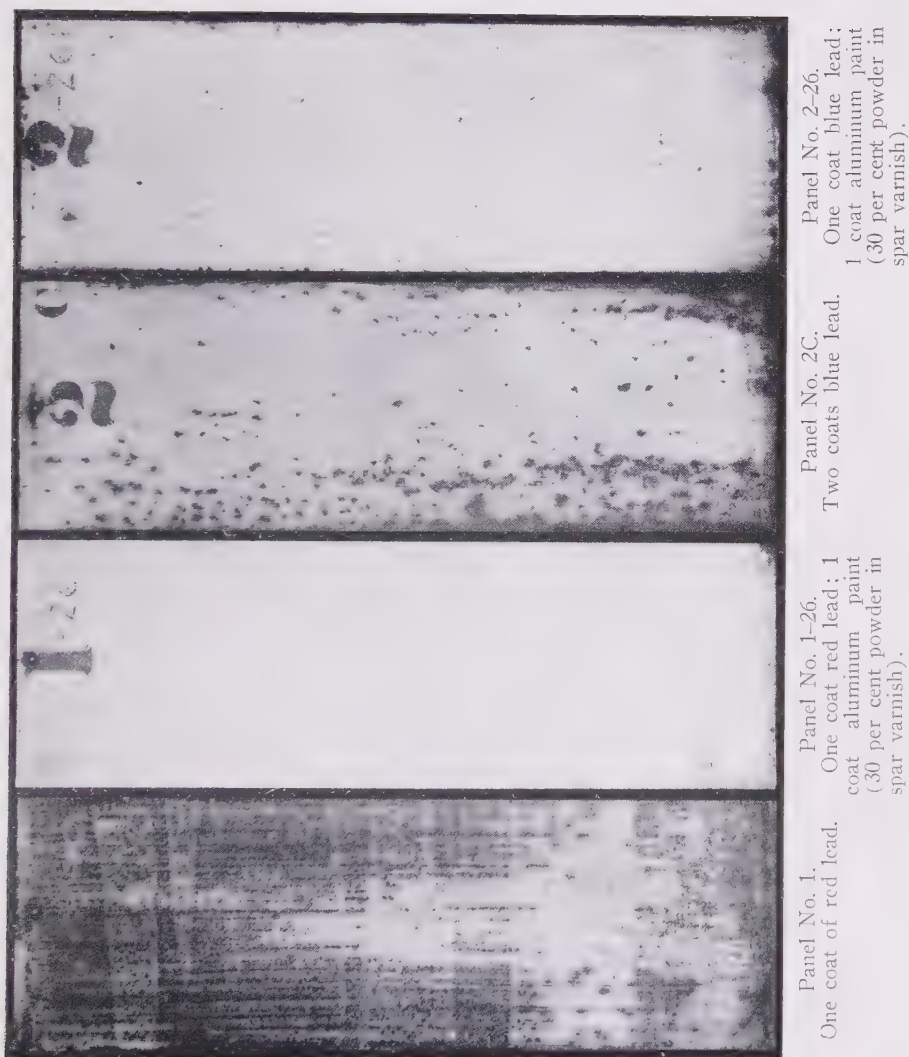


Fig. 5.—Appearance of painted steel panels after 52 months' exposure at Washington. (Courtesy of H. A. Gardner.)

1920. In fact, a couple of panels with aluminum paint were exposed at Atlantic City in May, 1919, and it was the promising behavior of this earlier test that inspired the second more comprehensive test begun in 1920. Circulars Nos. 130, 153, 187 and 231 of the Paint and Varnish Manufacturers' Association give the results of inspection of these panels after exposure for intervals of 9, 19, 31 and 52 months.

The conclusions to be drawn from these tests may be summarized briefly as follows:

Raw linseed oil, boiled linseed oil and spar varnish gave satisfactory life as vehicles for aluminum paint. The raw linseed oil seemed somewhat better in point of durability than boiled oil or spar varnish. The particular type of nitrocellulose lacquer or "dope" which was tried was comparatively short lived.

Tests were made using various quantities of powder from 10 to 40 per cent by weight. The best all-round results were secured using 25 per cent of powder; this is equivalent to a little more than two pounds of powder per gallon of vehicle. The use of 15 per cent powder gave a paint of lower durability, and more than 30 per cent of powder made the paint too thick to spread properly.

The powders employed were special products nominally designated as 200 mesh and 300 mesh; there was no marked difference in their performance. It has since been found unnecessary and undesirable that all of the powder particles be as fine as 300 or even 200 mesh.

Aluminum paint gave very satisfactory service as primer or as top coats over other primers. After 52 months' exposure at Washington, one coat of red lead or blue lead as primer with one top coat of aluminum paint was in "very good to excellent condition," and two coats of aluminum paint were reported as in "excellent condition" and "very good condition." The appearance of a number of these panels after 52 months' exposure is shown in Figures 5 and 6. As a protective coating for steel, the aluminum paint gave a good account of itself, although the results were only preliminary in many ways.

Bureau of Standards Tests.

The National Bureau of Standards, in 1920, also started a

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series of tests of aluminum paint coatings on steel. Walker and Hickson,⁸ reporting on these tests after 3½ years' exposure stated:

"The conclusions that may be drawn from these exposure tests are:

1. An aluminum paint containing from 25 to 30 per cent of aluminum powder in a vehicle composed of boiled linseed oil, or a mixture of boiled linseed oil and spar varnish, will prove to be a durable outside coat for metal when applied in 3 coats.

2. Two coats of these paints will give good service on metal; one coat only is not recommended.

3. An aluminum paint containing 15 per cent of the powder in spar varnish is not nearly the equal, for outdoor durability on metal, of one containing about twice as much (25 to 30 per cent) aluminum powder in a mixed vehicle of spar varnish and boiled linseed oil. This will hold for a one, two or three-coat job.

4. Aluminum paint containing boiled linseed oil without any spar varnish is somewhat more durable for outside use, under the conditions of our tests, than a paint containing an equal amount of the same aluminum powder but in a vehicle of two-thirds boiled linseed oil and one-third spar varnish."

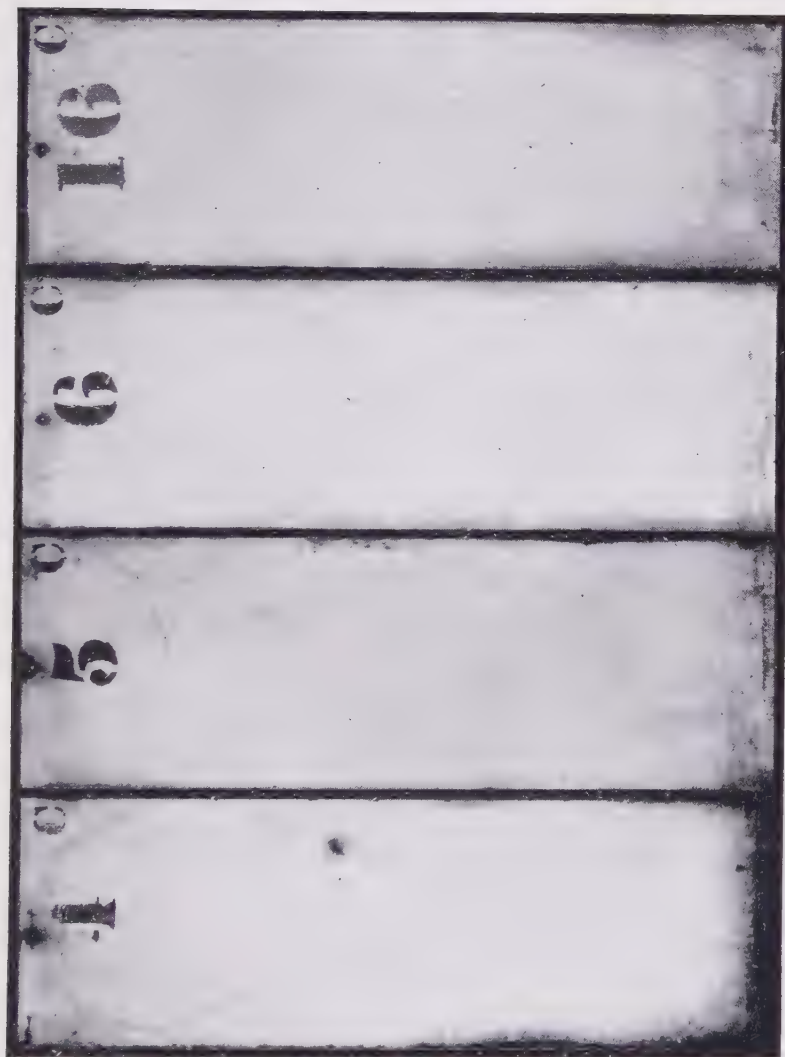
Additional tests were started in 1923, as mentioned in the article just referred to. All panels were in excellent condition after ten months' exposure, but no final report has been published.

Aluminum Company of America Tests.

The Research Bureau of Aluminum Company of America has undertaken extensive investigations into the many details of the preparation and use of aluminum paint. Some of the data from these tests have been published, but most have not. This experience will be drawn on in the detailed discussion of the properties of aluminum paint to be given in succeeding chapters.

A large number of paint and varnish manufacturers have also investigated the properties of aluminum paint as a preliminary

⁸ Some Observations on Aluminum Paint. P. H. Walker and E. F. Hickson, *Chem. and Met. Eng.*, Vol. 31, p. 693, 1924.



Panel No. 4C.

Two coats aluminum paint (15 per cent powder in spar varnish).

Panel No. 5C.

Two coats aluminum paint (25 per cent powder in boiled linseed oil).

Panel No. 6C.

Two coats aluminum paint (25 per cent powder in raw linseed oil).

Panel No. 16C.

Two coats aluminum paint (25 per cent powder in raw linseed oil).

FIG. 6.—Appearance of painted steel panels after 52 months' exposure at Washington. (Courtesy of H. A. Gardner.)

to the manufacture and sale of it. All of this intensive experimentation, as well as the very extensive and satisfactory commercial use of aluminum paint, has in a very short time established aluminum paint as one of the "standard" paints. One need not travel far to see it doing service on oil tanks, tank cars, refrigerator cars, water tanks, buses and trucks, structures of all kinds, factory interiors and exteriors, furnaces and boats, to name only a few of its important uses.

The fact is also worth emphasizing that not every aluminum paint is a good paint. Only good aluminum powder in a good vehicle adapted to the job in hand will give the satisfaction which the user expects to receive from aluminum paint.

Chapter 5.

Composition of Aluminum Paint.

In preparing aluminum paint, a generally satisfactory method is for the user to mix aluminum bronze powder and vehicle in the proper proportions as needed and then to apply the paint promptly, preferably the same day. Maximum leafing, brightness and hiding power are generally secured when the paint is not allowed to stand for an extended period after mixing. The advantages of mixing aluminum paint as it is used are such that the method is very widely employed. To secure the best results, it is obvious that both vehicle and powder should be adapted to the job in hand. The selection of a vehicle must be made with special reference to the behavior of the powder in it and the performance of the mixed paint on the surface to be painted.

Vehicle Requirements.

The requirements for the vehicle are, that when mixed with the "proper amount" of pigment, the paint shall spread and cover satisfactorily, have the proper appearance, dry to a tough, durable film, and exhibit the expected protective action. The first requirement of a vehicle, therefore, is that it shall have the proper "body" or viscosity. The painter, by spreading the paint with a brush, can very quickly decide whether it flows and levels properly. If the paint is too thin, it will not hide and protect properly, and if too thick, it cannot spread out to a uniform film of the right thickness without excessive effort in brushing. Within these extremes there is a range sufficiently broad to meet the individual preference of nearly every user. It is not sufficient that the vehicle have the desired viscosity. The mixed paint must also be sufficiently plastic so that when applied to a smooth vertical surface, it will not run, sag, or streak, but will set and dry to a smooth uniform film.



(a)

Aluminum Paint made with bodied
linseed oil.

(b)

Aluminum Paint made with raw
linseed oil.

FIG. 7.—Behavior of Raw Linseed Oil and Bodied Linseed Oil in
Aluminum Paint.

Difficulties with Raw Linseed Oil.

These considerations are very clearly illustrated when raw linseed oil is used as a vehicle for aluminum paint. Raw linseed oil has a viscosity as high as some other liquids which make satisfactory vehicles for aluminum paint. Nevertheless, aluminum powder mixed with linseed oil cannot be applied to smooth vertical surfaces without running and streaking. This is forcibly illustrated by Figure 7b, which shows the results of painting a vertical steel panel with such a mixture. The paint has not sufficient plasticity to remain in place, nor does it set sufficiently rapidly by drying to prevent a substantial amount of the paint running down to the bottom of the panel. However, on a rough surface, and particularly on a rough and porous surface, such a paint might do quite well.

The liquid vehicle alone is said to be "viscous," that is, it flows or deforms at a certain rate under the slightest stress. The mixture of powder and vehicle should, however, be plastic and not flow until a certain critical pressure or "yield value" is reached. Obviously a paint which is applied to a vertical surface should be sufficiently plastic so that it will not run or streak, but yet will level out to a smooth film.

The setting of the paint film is aided by the presence in the mixture of some volatile liquid. The ready evaporation of thinner from a paint film naturally "thickens" the remaining material and helps to hold it in place until the drying of the film has progressed sufficiently to accomplish this. In the case of raw linseed oil, there is no volatile thinner to evaporate and the aluminum paint made with it is generally too low in plasticity to set properly. In order to use linseed oil it becomes necessary to "body" it by some such method as heating and oxidation. Ordinary boiled linseed oil is somewhat better than raw linseed oil, but is still insufficiently bodied to be generally applicable. Where it can be properly applied, aluminum paint made with boiled linseed oil gives a very durable paint film. However, the group of oils known as "bodied" oils are very satisfactory in respect to consistency and have wide application. An aluminum paint film made with bodied linseed oil is shown in Figure 7a.

Bodied Linseed Oil.

Bodied linseed oil is made in two ways. One method is to heat linseed oil under carefully controlled temperatures of about 575° to 600°F for a number of hours, depending on the consistency required. The product is known as "heat bodied" or polymerized linseed oil and is of syrupy consistency. A somewhat quicker method is to blow air through the oil during heating, so as to accelerate the oxidation process which thickens the oil. Such an oil is known as a "blown" or oxidized linseed oil. Usually a bodied oil will require dilution with from 30 to 60 per cent thinner to reduce its consistency to the proper value for aluminum paint. The appropriate amount of drier must also be added to make it suitable as a paint vehicle.

The heat bodied oils are of high quality and make very durable vehicles for aluminum paint. A satisfactory mixture would be a heat bodied oil of such a consistency that after dilution with 40 per cent of mineral spirits it would have a viscosity of about 0.85 poise, corresponding to Tube C of the Gardner-Holdt comparison tubes. Sufficient drier should be incorporated so that the paint made by mixing two pounds of aluminum bronze powder with a gallon of the vehicle will set to touch in about 10 hours and dry hard in 24 to 30 hours. The heat bodied oils are also popularly known as "kettle bodied" oils.

Blown oil is a cheaper oil and makes a paint of substantially lower durability than when heat bodied oil is used. Where durability is not the important consideration, the blown oils may be employed. Aluminum paint made with heat bodied linseed oil naturally dries rather slowly, but the resulting paint film is quite distensible and long lived. Because of its slow drying characteristics, it is not best adapted for use in many places where rapid drying is essential, as in dusty or smoky locations, where a slow-drying paint film would become discolored before it set to touch. The use of an excessive amount of metallic drier in order to accelerate drying is also inadvisable because of its depreciating effect upon the durability of the paint. Under such conditions it is better to employ a varnish vehicle.

Varnish Vehicles.

Varnish may be said to be the universal vehicle for aluminum paint. The term "varnish" is, however, very inclusive, and the selection of varnishes satisfactory for aluminum paint is somewhat of a problem. The varnishes which are of primary interest in this connection are mixtures of oil, resin and volatile solvent which have been compounded by heating to produce liquids which, when applied in thin coats, dry to tough, transparent and more or less distensible films. A wide variety of oils may be employed, although linseed oil and combinations of linseed and tung oils are most commonly employed. The resins may be the natural resins, such as Congo, Kauri, Manila gum, etc., or the synthetic ester gum, which is made by esterifying rosin by heating it with lime and glycerine under suitable conditions.

The first essential for a varnish is that it shall have the proper consistency; the same considerations that were discussed in connection with linseed oil apply here. Having a varnish of proper consistency and drying time, attention should then be given to the properties of the dried varnish film. For durability, particularly where exposed to sunlight and weather, a tough film is desired with considerable resistance towards moisture and the smoke and fume of industrial regions. While the manufacture of varnishes, long an art, is now being brought under close chemical control, chemical analysis can still tell us very little about their properties, especially durability. The user must therefore depend on the recommendations or experience of the makers, or select vehicles as the result of physical tests made on the varnish film.

For interior use a satisfactory aluminum paint can be made from almost any good varnish of the proper consistency. For exterior use, where resistance to sunlight, air, water, smoke and fume is necessary, a special type of varnish is required which will give a tough, durable film. Such varnishes are designated as long oil varnishes, spar varnish, waterproof varnish, etc., and are characterized by having a much higher ratio of oil to gum than is found in interior varnishes. A high percentage of oil gives the varnish film distensibility and life, while the gum adds toughness and water resistance. Another requirement is that the proportion of volatile thinner be not too high. The thinner evaporates com-

pletely from the paint film, leaving only the non-volatile oil and gums to serve as a binder for the aluminum bronze powder. Mr. H. A. Gardner⁹ has investigated this factor and his conclusion is very much to the point:

"Greater durability was, as a rule, obtained from varnishes of fairly high non-volatile content, and by varnishes that had a substantial body. Varnishes of fairly high viscosity form films that are thicker than those of low viscosity. Consequently, the former usually wear for a longer period of time. It is conceivable that a varnish could be made, that would pass all the present specifications of the Federal Specifications Board, and which would still be of very thin body. Such a varnish, when brushed out, would present such a thin film that it might not be durable upon exposure."

It is also a general rule, based on experience, that the tougher varnish films are the more durable. Of course, in a strict comparison questions of composition and treatment are very important, but nevertheless, the generalization is remarkably useful in comparing varnishes. Mr. L. V. Pulsifer¹⁰ developed the Kauri Reduction Test as a means of measuring the "elasticity" or toughness of a varnish and also its probable durability. Mr. Pulsifer says that,—

"Elasticity is the most important factor in determining the service durability of a finishing varnish, and, other things being equal, the comparative durability of a series of varnishes will follow exactly their comparative elasticity. This factor may be successfully estimated in the laboratory by use of the so-called Kauri Reduction Test for Elasticity. This test was developed by the writer a number of years ago as the culmination of a long-extended and comprehensive series of experiments looking toward the perfection of a laboratory method for rapidly and accurately estimating the elasticity factor in a varnish. This test for elasticity was adopted by the Government during

⁹ Possible Relation of Body and Non-volatile to Durability of Spar Varnishes. Circular No. 260, Paint and Varnish Manufacturers' Association. February, 1926.

¹⁰ Accelerated Elasticity Test for Oleo-Resinous Varnishes (The Kauri Reduction Test). Proc. Am. Soc. Test. Mat., Vol. 22, Part I, p. 337 (1922).

the World War for determining the elasticity of varnishes offered for airplane use, and for eliminating those considered too inelastic for the purpose. It has since appeared in numerous specifications to replace the former slow and unsatisfactory panel exposure test."

Experience has indicated that a long oil varnish should have sufficient metallic drier incorporated so that it will set to touch in about 2 to 6 hours. A bodied linseed oil should be allowed a longer drying time, say 6 to 10 hours, to set to touch. Cobalt and manganese seem to be well adapted as driers. Lead driers have the disadvantage of permitting discoloration of the paint film by hydrogen sulphide if any substantial quantity of lead is present. The opinion is also held by some that lead drier adversely affects the color and luster of the pigment in a ready-mixed aluminum paint. It therefore seems advisable to keep the quantity of lead drier used to a minimum.

Powder Content of Paint.

The most generally satisfactory amount of aluminum bronze powder has been found to be about two pounds of powder per gallon of oil or varnish. This is in striking contrast to the lead pigments, for example, which are employed in amounts of about 10 to 25 pounds per gallon of oil. A typical varnish, such as used for aluminum paint, will weigh about 7.5 pounds to the gallon. The aluminum bronze powder has a bulking value of 0.056 gallon per pound of powder, so that two pounds of powder with a gallon of vehicle will make approximately $1\frac{1}{8}$ gallons of mixed paint. A simple calculation shows also that the pigment portion—aluminum bronze powder—constitutes about 21 per cent, by weight, of the paint. Aluminum bronze powder can be conveniently used up to 30 per cent, particularly if a vehicle of rather thin consistency is mixed with it. However, the addition of much more than this amount generally interferes with proper brushing of the paint, and the paint may likewise prove slightly less durable. If much less than 20 per cent powder is used, the durability will suffer.

The pyroxylin lacquers, to be discussed presently, can only be mixed with about one pound of powder per gallon if the proper spraying consistency is to be preserved. Where durability is im-

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portant, the number of coats of pigmented lacquer can be correspondingly increased.

Grade of Powder.

The grade of powder known as "Standard Varnish" has been found to be the one most generally useful in making aluminum paint. "Extra Brilliant" powder contains a higher percentage of large flakes and gives a somewhat brighter appearing paint film. The actual difference in reflectivity of aluminum paint made with Extra Brilliant powder, as compared with Standard Varnish, is only two or three per cent, but it may be distinctly noticeable to the eye. The surface of the paint made with Extra Brilliant is less smooth than that made with finer grades. On the other side of the picture, exposure tests conducted at a number of locations strongly indicate somewhat greater durability for the paints made with Standard Varnish powder. The use of Extra Fine powder is only indicated where a particularly smooth appearing paint film is desired, as for example in finishing tools and equipment.

Pyroxylin Lacquers.

The early tests gave rather poor exposure results for mixtures of cellulose nitrate lacquer and aluminum powder. Since that time, however, revolutionary changes have been made in the lacquer industry as the result of the development of the so-called "low viscosity" cellulose nitrate. The early cellulose nitrate or pyroxylin lacquers were limited in composition, because not more than about 6 ounces of pyroxylin could be dissolved in a gallon of lacquer and still leave the lacquer thin enough in consistency for satisfactory application. By changing the degree of nitration and the character of the solvent employed, the modern low viscosity lacquers carrying as much as 16 ounces of pyroxylin per gallon have been developed. These lacquers naturally give a very much thicker and more durable film on drying. In addition to the true solvents employed in these lacquers there are employed non-solvent thinners which beneficially modify the fluidity, rate of drying, etc. There are also added various materials called plasticizers, which increase the toughness of the lacquer film, and gums or resins which increase its adhesion and

luster. These lacquers, mixed with various colored pigments, have been extensively employed in automobile and furniture finishing and other places where a quick drying film of good wearing qualities and attractive appearance is desired.

Aluminum bronze powder can be very successfully applied in pyroxylin lacquers and the mixture gives the usual quick drying lacquer film. Aluminum bronze powder does not leaf in pyroxylin lacquer, but gives a film of somewhat frosted appearance with high light diffusion and attractive appearance. In common with other pigments, less aluminum bronze powder can be incorporated in these lacquers than in oil base paints; about one pound per gallon of lacquer is a suitable amount. The usual method of applying pyroxylin lacquers has been by spraying. More recently, however, "brushing" lacquers have been developed which dry in about ten to thirty minutes. Aluminum bronze powder works well in both types of lacquer. In applying lacquers, care should be taken to use only the special thinner supplied or recommended by the manufacturer for mixing with his lacquer.

The durability of lacquer films with outdoor exposure, sunshine and rain, is greatly increased by the addition of metallic aluminum flakes. Sunlight is one of the important factors in the deterioration of lacquer films and the protection given by aluminum bronze powder is both obvious and valuable.

Bronzing Liquids.

Another group of vehicles used for aluminum paint is commonly known as bronzing liquids. The term has no technical significance except as it has been applied to a variety of liquids used with aluminum bronze powder for decorating radiators, picture frames, fixtures and the like. A commonly used vehicle of this type is the so-called "gloss oil." Gloss oils are solutions of treated rosin in mineral spirits, and even the best contain only a small amount of the drying oils such as linseed or tung oil. They dry rapidly—usually in less than one hour—and possess little toughness and durability. They are, however, cheap and for many purposes make a satisfactory vehicle for aluminum paint, particularly where durability is relatively unimportant. Although their lack of weather resistance is the chief drawback to their use, nevertheless the protective effect of aluminum bronze

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powder is so marked that they give fair service on metal surfaces outdoors. Spirit varnishes, of which a solution of shellac in alcohol is an example, may also be used with aluminum powder. They are likewise lacking in toughness and should only be employed where this feature is not a drawback.

The well known and fragrant "banana oil" bronzing liquid is a type now infrequently used except for decorative purposes. It consists of a solution of nitrocellulose in amyl acetate. It has little to recommend it except its property of rapid drying.

Bituminous Paints.

Still another class of vehicles finding employment in aluminum paint are made from a bituminous base. The bituminous materials used in such paints are quite varied in nature and comprise asphalt, asphaltite, tar, pitch, and the like. Bituminous paints are made by compounding these substances with volatile solvents, and in some cases, vegetable drying oils, resins, fillers and pigments are added. One of their important characteristics is high moisture resistance, or waterproofing power. They are, however, sensitive to deterioration by sunlight, and as a class, readily check and alligator on exposure to the weather.

In some bituminous paints aluminum bronze powder will leaf freely and to such an extent as to give the paint film a brilliant metallic aluminum surface without any apparent trace of the black bituminous paint in which it is incorporated.¹¹ If such a bituminous-aluminum paint is spread on glass, it is interesting to compare the black base, looking through the glass from the back, with the brilliant aluminum leafed surface seen from the top. Some bituminous paints permit little or no leafing of the aluminum bronze powder; in general, it may be said that those employing a coal-tar solvent, such as toluol or xylol, leaf the best. One other condition for ready leafing is that the mixture shall be thin enough in consistency to permit the free movement of the aluminum flakes in the "wet" paint film. The leafing power usually diminishes on standing in the mixed paint, so that such paints must be mixed and used as needed.

Exposure tests show that aluminum powder lends to such paints marked protection against sunlight. While it will not in some

¹¹ Fleming, U. S. Patent 1,568,215.

cases entirely prevent checking or alligating of the paint film, it reduces the extent and seriousness of such defects, and adds materially to the life of the paint film. In cases where it is desired to have a priming coat of bituminous paint next to a metal surface, a top coat of oil base (spar varnish) aluminum paint can be applied over the bituminous paint without bleeding through of the black base.

Lacquers.

Lacquers made with synthetic resins, such as Bakelite, may also be employed with aluminum powder. They are especially useful for resisting softening or attack by agencies such as turpentine or gasoline, which injure oil base paints. Bakelite with aluminum powder makes a good baking enamel. It also makes an excellent finish for metal surfaces which are to be heated to relatively high temperatures.

Chapter 6.

Specification and Testing.

Of all the vehicles for aluminum paint, the long oil varnish is the most generally useful. This has been demonstrated by field and laboratory test. The results of this varied experience have been incorporated in a specification which outlines the minimum requirements for long oil varnishes which will make durable aluminum paint. In this specification the main dependence is placed on physical tests that insure proper performance, and not on the composition of the varnish. Even though the composition of a varnish could be accurately determined by analysis—which it cannot—the user is primarily interested in its performance, and performance tests are therefore a logical requirement. Following the specification will be given directions for carrying out the tests and various notes on the tests.

Standard Specification—Aluminum Company of America

Exterior Varnish Vehicle for Aluminum Paint

The vehicle for use with aluminum bronze powder shall fulfill the following requirements:

1. The varnish shall contain not less than 50 per cent by weight of non-volatile oils and gums.
2. The varnish shall pass a 60 per cent Kauri Reduction Test, as specified in Federal Specifications Board Standard Specification No. 18b.
3. The varnish shall be of such consistency that when thoroughly mixed with aluminum bronze powder in the proportion of two pounds per gallon of vehicle, the paint shall show satisfactory spreading qualities, and shall not run or sag when applied to a smooth vertical surface. The viscosity of the varnish shall be between 0.5 and 1.25 poises.

4. The paint shall set to touch in not less than 2 nor more than 6 hours, and dry hard and tough in not more than 24 hours.

The Federal Specifications Board has given in their Standard Specification No. 18b (Bureau of Standards Circular No. 103) directions for carrying out the determination of non-volatile content, drying time, Kauri reduction test, etc., and these methods are included here for the benefit of those who may wish to make these tests.

Testing Methods

(Taken from Bureau of Standards Circular No. 103)

Samples will, in general, be tested by the following methods: The tin panels used in the following tests shall all be cut from bright tin plate weighing not more than 25 grams nor less than 19 grams per square decimeter (0.51 to 0.39 pound per square foot). Commercial gage No. 31 bright tin plate should weigh about 0.44 pound per square foot; (it is important that the tin plate used shall be within the limits set). The panels shall be about 7.5 by 13 cm (3 by 5 inches), and must be thoroughly cleaned with benzol immediately before using.

Non-volatile Matter. Place a portion of the sample in a stoppered bottle or weighing pipette. Weigh container and sample. Transfer about 1.5 grams of the sample to a weighed flat-bottomed metal dish about 8 cm in diameter (a friction-top can plug). Weigh container again and by difference calculate the exact weight of the portion of sample transferred to the weighed dish. Heat dish and contents in an oven maintained at 105°C to 110°C (221° to 230°F) for three hours. Cool and weigh. From the weight of the residue left in the dish and weight of the sample taken, calculate the percentage of non-volatile residue.

*Drying Time.*¹² Pour the varnish (aluminum paint) on one of the tin panels described above. Place the panel in a nearly vertical position in a well-ventilated room but not in the direct rays of the sun. The atmosphere of this room must be free from products of combustion or laboratory fumes. The temperature of the room should be from 21° to 32°C (70° to 90° F). The film is tested at points not less than 2.5 cm (1 inch) from the edges of the film by

¹² In applying this test it should be noted that the drying time referred to in the specification is for the mixed paint and not for the varnish. Hence the words "aluminum paint" should be read instead of varnish.

touching lightly with the finger. The varnish is considered to have set to touch when gentle pressure of the finger shows a tacky condition but none of the varnish adheres to the finger. The varnish is considered to have dried hard when the pressure that can be exerted between the thumb and finger does not move the film or leave a mark which remains noticeable after the spot is lightly polished. If rapid light rubbing breaks the surface, the sample is considered not to have satisfactorily dried hard. In case the test shows time of setting to touch or drying hard more than 6 and 24 hours, respectively, two additional tests shall be run on different days, and if the varnish does not meet the above drying and hardening requirements on both of these additional tests, it shall be considered unsatisfactory.

Toughness. The toughness of the varnish is determined by the Kauri reduction test as follows: By proportionately reducing its toughness by the addition of a standard solution of "run-Kauri" gum in pure spirits of turpentine.

(1) *Preparation of the "Run-Kauri."* Arrange a distillation flask, water-cooled condenser and a tared receiver on a balance. Place in the flask about one-third of its volumetric capacity of clear, bright, hard pieces of Kauri gum broken to pea size. Carefully melt and distill until 25 per cent by weight of the gum taken is collected in the tared receiver. Pour the residue into a clean pan, and when cold break up into small pieces.

(2) *Preparation of Standard "Run-Kauri" Solution.* Place a small quantity of the broken pieces of run-Kauri together with twice its weight of freshly re-distilled spirits of turpentine, using only that portion distilling over between 153° and 170°C (308° and 338°F) in a carefully tared beaker. Dissolve by heating to a temperature of about 149°C (300°F) and bring back to correct weight when cold by the addition of the amount of re-distilled spirits of turpentine necessary to replace the loss by evaporation during the dissolving of the gum.

(3) *Reduction of the Varnish.* Having carefully determined the non-volatile content of the varnish, take 100 grams of the varnish and add to it an amount of the standard run-Kauri solution equivalent to 60 per cent, by weight, of the non-volatile matter in the varnish. Mix the varnish and the solution thoroughly.

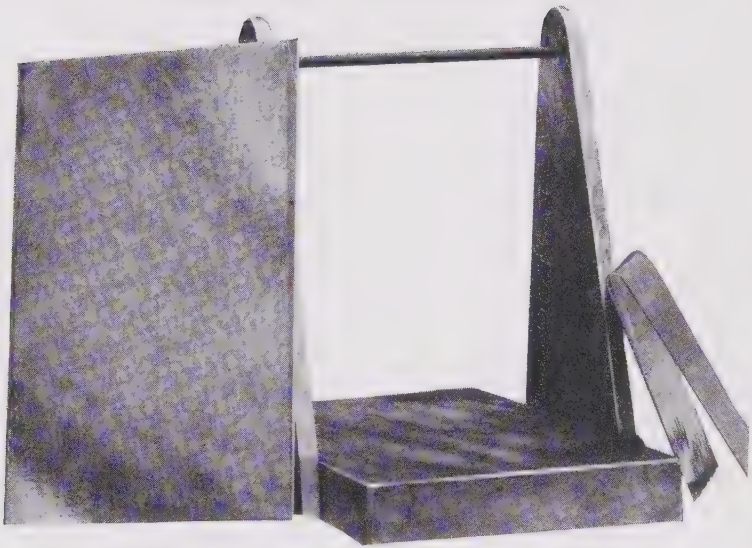


FIG. 8.—Kauri reduction test panel, rod for bending panel and panel after bending.

(4) *Application of the Varnish.* Flow a coat of the varnish thus reduced on one of the tin panels described above and let stand in a nearly vertical position at room temperature for one hour. Next place the panel in a horizontal position in a properly ventilated oven and bake for 5 hours at 95° to 100°C. Remove the panel from the oven and allow to cool at room temperature, preferably 24°C (75°F) for one hour.

(5) *Bending the Panel.* Place the panel with the varnished side uppermost over a 3 mm ($\frac{1}{8}$ inch) rod, held firmly by suitable supports, at a point equally distant from the top and bottom edges of the panel and bend the panel double rapidly. The varnish must show no cracking whatsoever at the point of bending. For accurate results, the bending of the panel should always be done at 24°C (75°F) for a lowering of the temperature will lower the percentage of reduction that the varnish will stand without cracking, while an increase in the temperature increases the percentage of reduction that the varnish will stand.

Viscosity.

The viscosity of a vehicle can be very quickly estimated by the "air-bubble" method. In making this test, a small tube is filled with the liquid, and a small air space left between the surface of the liquid and the cork. When the tube is inverted the air-bubble rises through the liquid at a rate depending upon the viscosity of the liquid. The speed of the air-bubble can be compared with that of standard tubes of the same diameter and the same size of bubble and containing liquids of known viscosity. Gardner and Holdt¹³ have devised a series of comparison tubes for carrying out this test in a simple manner and their apparatus has been extensively employed. It consists of a case holding twenty tubes filled with a series of mineral oils of graded viscosity, and each having enclosed an air-bubble of the same size. The tubes are lettered from A to T, and the contained oils have absolute viscosities (at 25°C) of from 0.50 to 5.50 poises. In making an aluminum paint, a vehicle having a viscosity corresponding to that of Tube C (0.85 poise) has been found to be the most generally satisfactory. However, depending on the ideas and require-

¹³ Paint and Varnish Manufacturers' Association, Circular No. 128, 1921.

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ments of the user, viscosities within the range of Tubes A to E (0.50 to 1.25 poise) will be acceptable.

As previously explained in connection with the use of linseed oil, consistency alone is not a controlling factor in determining the suitability of a vehicle for aluminum paint, and for that reason paragraph 3 of the specification states that—"the vehicle when mixed with aluminum bronze powder in the proportion of 2 pounds of powder per gallon of vehicle shall not run or sag when applied to a smooth vertical surface." This test can be made by mixing about 100 cc ($\frac{1}{4}$ pint) of paint in a small dish and applying it by means of a 2-inch varnish brush to a clean steel panel at least 12 inches long and 6 or more inches wide. The panel should be painted while in a vertical position, or if painted horizontally, should be set up vertically at once and left in that position until set to touch. Any defect in the paint film, such as running or sagging, should then be noted. In addition to running and sagging and the degree and extent of leafing, the spreading and leveling of the paint film and the absence of brush marks can be observed in this test. While it is hard to define such a test quantitatively, the results are usually quite obvious and should enable one with a little experience to tell much about the working qualities of an aluminum paint.

Exposure Tests.

What is usually the most important test of a paint is the determination of its durability. The best test, of course, is a performance test made under the actual conditions of service. In most cases, this would take a long time to yield definite results, so that a variety of accelerated tests have been proposed and investigated. Since light, and particularly ultra-violet light, is a potent agent in the destruction of paint films, most accelerated tests employ exposure to ultra-violet light as one of the conditions. Other factors are moisture, heat, cold, oxygen, ozone, sulphur dioxide, etc., and according to the ideas of the investigator, the paint under test is exposed to light, artificial rain, refrigeration, etc., in cycles until definite failure of the paint film occurs. Alternate wetting and drying, as well as heating and cooling, combined with the action of light, provide a very severe exposure test for any paint film. The exact control of conditions is usually

sufficiently difficult so that comparison or control tests must be run simultaneously with the paint under test.

The more usual durability test is the weather exposure test. Panels of steel or wood are coated with the paints under test and exposed continuously to the weather. Weather itself is about as variable a condition as one could find, but over extended periods its effects are reasonably uniform. Moreover, it varies with geographical location and the behavior of paint films in different climates may vary correspondingly. No set of artificial conditions exactly duplicate the effects of weather exposure, so that exposure tests still remain the chief reliance in testing paints for outdoor service.

The panels for exposure will vary in size according to the ideas of the tester and may be modified somewhat by the space available for test racks. The steel panels shown in Figure 9 are 8" x 24" in size and cut from 14 gage mild steel. Wood test panels are commonly made from white pine, western yellow pine, or poplar, unless the performance of the paint on some special wood is to be tested. Results are usually desired as quickly as possible, and this is obtained by placing the panels and racks to face south and supporting the panels at an inclination of 45 degrees. In this way the panels receive the maximum light exposure,—in fact, the weathering is accelerated about 50 to 100 per cent as compared with the vertical position for panels. The weathering can be further accelerated by sprinkling the panels every day that nature doesn't attend to this feature. This can be attended to by spray pipes located above the panels, or by the common sprinkling-can manually operated. In some cases seaside conditions have been partially simulated by using a salt water spray. The alternate wetting and drying of the paint film, of course, accelerates deterioration.

Where exposure under normal service conditions is desired, rather elaborate "test fences" have been designed. These structures have been particularly adapted for the testing of paints for wood, and the test panels have been mounted and painted to simulate the conditions existing in frame house construction.

The panels should be examined at regular intervals for evidence of failure. On steel, the most obvious sign of failure is the appearance of rust. Incipient rusting under aluminum paint may first show itself as a slight darkening of the paint film, scarcely visible

with a dark colored paint. Many months of additional service may be secured before repainting is indicated.

In the case of wood, weathering of the wood and failure of the paint must be correlated. In examining paint it is customary to look for the defects known as checking, alligatoring, chalking, cracking, blistering, scaling, and peeling. It frequently happens that flaking and scaling of the paint is caused by checking of the wood. The checking of the wood may be the result of deterioration in the moisture-proofing power of the paint film. A vicious cycle of deterioration of wood and paint is thus established. In examining wood test panels it is well, therefore, to rate them both on the protection rendered the wood and the appearance of the paint film. This point is more fully discussed in Chapter 9.

Checking and alligatoring are of infrequent occurrence with aluminum paint made with oil base vehicles; in all of the tests by the author at New Kensington only a few panels were found which showed either one of these defects. Chalking occurs to a slight and beneficial extent, but it is usually inappreciable compared with the common performance of many other pigments. Because of the protection against light and moisture which the metal flakes afford the vehicle, aluminum paint films retain their distensibility and life for a very long time.



FIG. 9.—Exposure Test Racks at New Kensington, Pennsylvania.

Chapter 7.

Special Properties and Uses of Aluminum Paint.

Reflectivity.

One of the most obvious as well as useful properties of aluminum paint is its high reflectivity. Sheet aluminum, clean and bright, may have a reflectivity as high as 85 per cent, or even slightly higher, according to the composition and surface condition. This value is an upper limit towards which aluminum paint may reach but which it probably cannot attain. As previously mentioned, the stamping process, when too long continued, tends to darken the powder. The vehicle in which the powder is suspended may also have an effect, and the distribution of powder in the dried paint film is also a factor in determining the reflectivity. As a result, the maximum reflectivity observed in aluminum paint films is about 75 per cent. In practice, average performance will vary between 60 and 75 per cent.

The highest reflectivity is obtained with Extra Brilliant powder. According to a series of precise measurements, this advantage in reflectivity is only about 2 or 3 per cent over that of Standard Varnish powder. Such a difference is within the natural limits of variation of mixing, applying and measuring the same paint. The Extra Brilliant powder with its coarser flakes gives a somewhat rougher paint film with a strongly diffusing surface. There is little difference in reflectivity to be noted between paint films made with Standard Varnish and Extra Fine Varnish, although the Extra Fine powder gives a film of smoother texture.

At first thought, the color of the vehicle might be considered to have a substantial effect upon the color and brightness of the paint film. Measurements show, however, that within wide limits, this effect is inappreciable. Aluminum paint made with crystal clear oil had no higher reflectivity than one made with a deep orange red oil. The film of oil above the metal particles is evi-

dently so thin as to have little effect on the resultant color and reflectivity. It is unnecessary, therefore, to employ a very light colored vehicle to secure a bright paint film.

The degree of leafing does, however, have an important influence on reflectivity. Unpolished powder gives a paint film without leafing and has about ten per cent lower reflectivity than one made with the same grade of polished powder. More specular reflection and less diffuse reflection is obtained from a well leafed surface. In aluminum-pyroxylin finishes where no leafing occurs, the film usually has a "frosted" surface but is nevertheless very bright in appearance. The maximum reflectivity of aluminum paint is developed in one, or at best, two coats, even when applied over a black or dark surface. This result may be ascribed to the complete opacity of the aluminum flakes.

Aluminum Paint on Oil Tanks.

A major use of aluminum paint has been for the painting of oil tanks with the twofold object of protecting the steel tank from corrosion and for reducing evaporation losses. Until recent years the extent to which sunlight increased the evaporation loss from oil storage tanks was scarcely realized. In the southern oil fields of the United States, solar radiation of 4 to 5 Btu per square foot per minute is common on clear days. On the area of a tank normal to the sun's rays, this will amount to a very substantial heat input and unless it is properly dissipated may raise the oil temperature many degrees.

The Bureau of Mines has published some of the data they have collected in their study of ways and means of reducing evaporation losses in the handling and storage of petroleum. The first step to be taken is to make all containers as vapor-tight as possible. When this has been accomplished the evaporation losses are largely due to the "breathing" out of air saturated with light oil during the heating of the tank, and the "breathing" in of fresh air during cooling, which will be saturated with oil vapor to be expelled in the next cycle. The amount of oil vapor required to saturate the air increases rapidly as the temperature of the oil rises. The vapor pressure of a typical crude oil increased from 4 inches to 6 inches of mercury in being heated from 70° to 100° F. It is desirable, therefore, to keep the oil as uniformly cool as possible.

A practical test of the efficiency of various paints on oil tanks has been carried out by the Bureau of Mines in coöperation with the State of Oklahoma. The results of the test are reported by Ludwig Schmidt in Report Serial No. 2677 of the Bureau of Mines. Four 55,000-barrel storage tanks were used for these tests and they were painted black, red, gray and aluminum, as being colors much used in the oil industry. Schmidt states that—"every effort was made to keep these tanks vapor-tight throughout the duration of the test. Before the initial gage was made, each tank was inspected and every leak caulked. The last coat of paint was applied after the tanks were filled with oil. The roof of each tank was painted at that time. The tanks were filled with fresh Burbank crude pumped directly from vapor-tight lease stock tanks." This oil had an average gasoline and naphtha content of 29 per cent.

The test ran from January, 1924, to January, 1925, and the results therefore apply to average conditions throughout the year. The volume and composition of the oil were determined every month. Recording thermometers made a record of the vapor temperatures in the tanks. The following table summarizes the results on evaporation losses.

TABLE 2.

EVAPORATION LOSSES FROM OIL TANKS IN BUREAU OF MINES' TESTS.

Color of Tank	Initial Gage Barrels	Evaporation Loss in one year Barrels	Loss in Gravity in one year A.P.I.
Black	52,058	649	.6°
Red	53,294	609	.5
Gray	53,192	547	.3
Aluminum	53,418	447	.2

The results are eminently favorable to aluminum, and this in spite of the fact, as stated in the report, "that the roof and part of the side of the tank painted with aluminum were covered with oil when a lead line on a nearby flow tank broke. The oil was not cleaned off completely for several weeks. Therefore the tank was almost black during a part of the test."

Schmidt also notes that "the red, gray and aluminum tanks were located on leases that were being developed in the Burbank field. Therefore during the hot summer months the tanks were coated

with a thin film of dust. The dust was usually oily, due to the large quantities of gas and oil vapor in the air, and clung to the tank tenaciously. This condition had a tendency to reduce the heat reflecting properties of the colors and to place all of the tanks in the same class as to color. The effect of the dust was greatest on the gray and aluminum tanks. The dust was readily washed off by rains, so it did not materially affect the results when the entire period of the test is considered."

The aluminum paint showed a saving of at least 200 barrels per year compared with black paint, and 100 barrels compared with gray paint. The report concludes with the statement that the "results are believed to be conservative, and under slightly different conditions, the differences between the results obtained with the light and dark colored paints would doubtless be more marked."

If the temperature in the tank did not vary, there would be little evaporation loss from "breathing" in a tight tank, irrespective of its color. In the Bureau of Mines report just referred to, the average daily maximum variations in temperature of the four tanks were as follows: black, 32° F.; red, 29° F.; gray, 25° F.; aluminum, 23° F. These data, together with Bureau of Mines Technical Paper No. 319 by J. H. Wiggins, indirectly afford a comparison of white paint with aluminum paint.

Vapor temperatures measured in tanks in the Pennsylvania field under somewhat cooler conditions than those in the Mid-Continent field showed the following average daily maximum variations in August (same time as above):—black, 27° F.; red, 25° F.; white, 18° F. The aluminum tank, according to Schmidt's report, showed an average daily maximum fluctuation in temperature which was 9° F. less than in the case of the black tank. In the other series of tests reported by Wiggins the fluctuation in the white tank was also 9° F. less than that in the black tank, indicating approximately the same temperature efficiency from that standpoint for the white and aluminum painted tanks. The advantages of aluminum paint lie in its greater durability, hiding and covering power.

Emissivity.

A property closely related to the reflectivity of aluminum is its emissivity or radiating power. Like other metals, aluminum has a low emissivity and aluminum paint shares this characteristic,

although not to quite the same degree. The available evidence indicates that the emissivity of aluminum paint at temperatures of 40° C. (104° F.) is only about 30 per cent of that of a "black body," the theoretically perfect radiator.

Reflection, radiation, conduction and convection are the important factors in the heating and cooling of bodies. Reflection has already been considered. Conduction is not in general affected by the character of the surface, whether painted or not, and the effect of paint on convection is usually a secondary one. The difference between heat transfer by convection and by radiation can be illustrated by the common steam radiator. If the hand is held above the hot radiator, one feels the warm air currents ascending which are transferring heat from the radiator by convection. However, if the hand is held at some little distance from the side, the heat received is mainly by radiation from the heated surface. This radiated heat always travels in straight lines, but air convection currents usually pursue an irregular course.

The heat radiated by a body is relatively low at ordinary temperatures, say up to the boiling point of water. However, the loss of heat by radiation is proportional to the fourth power of the absolute temperature, and with increasing temperature it quickly becomes a dominating factor in heat transfer, since the heat loss by convection increases at a much slower rate. Just as the reflectivity of a substance may vary with the character or wave length of the incident light, so the emissivity of a body varies with the temperature at which it is radiating. The reflectivity of aluminum, and presumably of aluminum paint, is greater for infra-red or the long heat waves than for visible light or energy. The radiation from bodies at and near room temperatures is mostly in the infra-red region; the emissivity of aluminum paint at such temperatures is correspondingly low.

Coblentz and Hughes¹⁴ of the National Bureau of Standards have made a study of paints for decreasing or increasing heat radiation from surfaces. They found aluminum paint to have an emissivity (at atmospheric temperature or thereabouts) about 30 per cent of that of white lead paint. The white paint had as high an emissivity (within 4 per cent) as that of a lampblack paint. Aluminum paint can be used on surfaces which are heated to

¹⁴ Technologic Paper No. 254 (1924), Bureau of Standards.

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temperatures up to a dull red heat and its effect in reducing heat losses at such temperatures is very great.

Aluminum Paint on Furnaces.

As an illustration, the test given by the author in an article entitled "Aluminum Paint—A Heat Saver," may be cited: ¹⁵

"A series of tests was made upon an electric furnace of the laboratory type used for heating tubes in combustion analyses. As originally made, it was painted black with white composition-board ends. When operated in this condition, it was found by a number of observations sufficient to determine average performance, that with a power input of about 630 watts (at 110 volts) the center of the furnace reached a temperature of 954 deg. C. (1,749 deg. F.). After applying a coat of aluminum paint to the exterior, it was found that with exactly the same power input, the temperature reached was just 22 deg. C. (40 deg. F.) higher, namely, 976 deg. C. (1,789 deg. F.). Obviously the original temperature could have been maintained with a smaller power input with the aluminum painted surface. With furnaces operating at a higher temperature, the gain would be even greater. In many cases the upward extension of the attainable temperature, which can be reached by the use of aluminum paint, is particularly desirable. If a higher temperature is not necessary or desired, the operating temperature can be maintained with a smaller power input than when an ordinary brick or iron surface is employed.

An additional important advantage of the aluminum paint on furnaces is that it makes the neighborhood of the furnaces more comfortable for the workmen, since they receive less heat by radiation. In one particular case, two identical furnaces stood about 12 feet apart. One was finished with aluminum paint and the other with black paint. Standing between and equidistant from the furnaces, one could not help but notice the greater amount of radiant heat coming from the black furnace.

Of course, the surface of the aluminum painted furnace is actually hotter than if it were not so painted, because a larger proportion of the heat must be carried away by convec-

¹⁵ Chem. and Met. Eng., Vol. 33, p. 551, 1926.

tion; the aluminum paint dams up the heat, to use a crude analogy. In the case of the laboratory furnace previously cited, a particular point on the surface was at a temperature of 168 deg. C. (334 deg. F.) when painted black, and 224 deg. C. (435 deg. F.) when coated with aluminum paint. With a higher surface temperature, a greater amount of heat can be dissipated by convection."

Many are making practical use of the low emissivity of aluminum paint on furnaces of all types and sizes from the laboratory furnace just described to large fuel-fired and electric furnaces. An electric furnace installed at New Kensington was received from the maker with a coat of black paint. After installation it was given a coat of aluminum paint; on its initial test it did enough better than the average performance of this type of furnace to leave the maker puzzled as to the improvement in efficiency until told about the effect of aluminum paint.

The selection of the proper type of vehicle and its application are very important points in the painting of surfaces which are to be heated. Where the surface is to be heated up to temperatures of about 200° C. (392° F.), almost any varnish vehicle will serve satisfactorily. It should preferably be of rather thin consistency and should be diluted, if necessary, to give a freely flowing paint. Where the surface reaches temperatures of about 250° C. to 400° C. (482° F. to 752° F.), the gloss oil or spirit varnish type of vehicle usually works better. These vehicles are usually quite thin in consistency, and contain a large proportion of volatile material. Bakelite lacquer is suitable for this purpose. At such temperatures as those mentioned, the vehicle may burn out, but if the paint has been applied to a clean iron surface, the flake aluminum remains closely adherent to it. Some component of the vehicle appears to flux the metallic powder to the iron surface in such a way as to give excellent adherence even though the organic material burns out completely. With a suitable vehicle, the adherence is so remarkable as to give the impression that the metallic aluminum had been alloyed with the iron, although close examination shows no evidence of alloying. The aluminum flakes retain their characteristic color even up to the melting point of aluminum. It is essential, however, that the paint be applied to a clean iron surface, free from rust and grease, and that it be allowed to dry

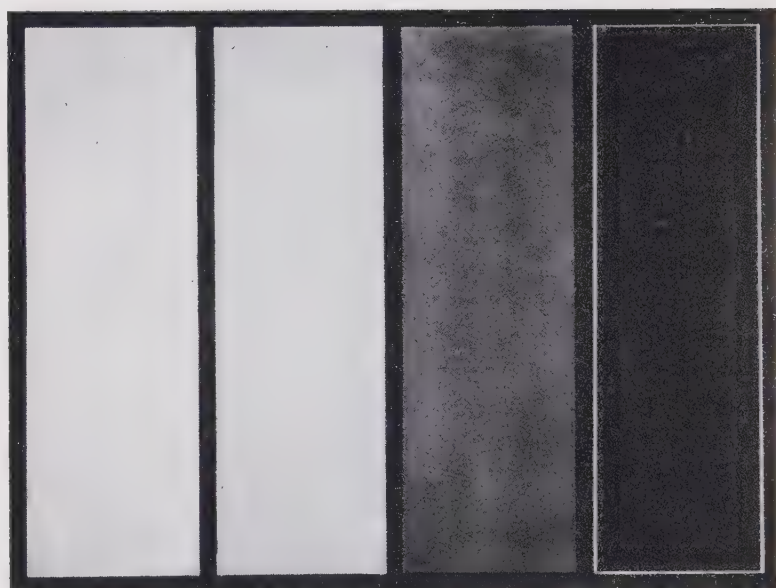
thoroughly before being heated. These vehicles are not particularly weather resistant and should not be expected to stand both high temperatures and weather exposure.

Aluminum Paint on Radiators.

The use of aluminum paint on house heating radiators has been a much-debated subject and some rather extreme views have been expressed. A steam-heated radiator operates at a low enough temperature so that convection is the important factor in transferring heat to the room. For this reason, even though the emissivity of aluminum paint be but 30 per cent of that of a black or other good radiating paint, the rate of heat dissipation from the radiator is only decreased about 10 to 15 per cent thereby. Tests carried out in the Research Laboratories of Aluminum Company of America on a 2-column, 4-section radiator of the usual type under standard operating conditions showed a reduction in heat dissipation of 13.2 per cent with an aluminum painted surface in comparison with the rusty iron surface, or 11.1 per cent in comparison with the surface coated with white paint. It should be noted in this connection that the aluminum painted radiator runs with a hotter surface, which increases the air convection losses. This is desirable, since it is the warm air from the radiator that gives a feeling of comfort. The radiated heat travels largely to walls, furniture and other objects in a direct line. When desired, the emissivity of aluminum paint can be markedly increased by tinting with a non-metallic pigment as described on page 64.

Coblentz and Hughes in the article previously referred to have suggested the use of aluminum paint on the inside of auto tops, tents, metal roofs, balloon hangars, observatories and other structures which it is desired to keep from heating up in the sunlight. For the top surface they recommend a white paint with a higher reflectivity than aluminum paint, in order to secure maximum reflection and emission. In actual practice, the superior durability of aluminum paint, and the fact that it gives maximum reflectivity with fewer coats and generally maintains its high reflectivity better than a white paint, are points to be considered.

Carl G. F. Zobel (J. Optical Society of America, Vol. 14, p. 409, 1927) found that the heat flow through a slate roof was



One Coat
Aluminum Paint.

Five Coats
White Paint.

Three Coats
White Paint.

One Coat
White Paint.

FIG. 10.—Comparative Opacity of Aluminum Paint and White Paint as shown by exposing photographic paper through the respective paint films; the transparency of the paint films and consequently the depth of exposure of the paper decreases from right to left of the picture.

reduced 38 per cent by dusting on aluminum bronze powder without any binder.

Opacity.

A marked characteristic of a metal is its perfect opacity. It is true that exceptionally thin metal films have been prepared which show some light transmission, but for practical purposes the flakes of aluminum bronze powder are completely opaque to light. An easy way to test this point is to paint a coat of aluminum paint on glass and hold it before the filament of an electric light. If complete covering has been secured, the filament will be entirely obscured. In contrast with this a similar test of five coats of white paint on glass showed very substantial light transmission. It is because of the complete opacity of the aluminum flakes that the usual methods of determining the hiding power of a paint are inapplicable to aluminum paint.

The high opacity of aluminum paint is illustrated by Figure 10. The figure is reproduced from a print which was made by simultaneously exposing photographic printing paper through a series of paint films. The area of paper beneath the aluminum paint film was pure white, showing no exposure and hence no light transmission. The increase in opacity of the white paint films with increasing number of coats is apparent, but there is substantial light transmission even with five coats of white paint. A commercial titanox-zinc oxide paint, which has about the best hiding power of any of the white paints, was used in this test.

Aluminum paint will hide completely in one coat, providing a well leafed uniform coating is secured. For most practical purposes the ideal of a well leafed and uniform coating can be secured by the selection of a vehicle of the proper character and consistency, and using the mixed paint while it leafs readily. Its remarkable hiding power, coupled with its substantial reflecting power make aluminum paint very useful for interior walls and surfaces where lighting efficiency is desired, and where the advantage of using only one, or at most, two coats of paint is important.

The hiding power of a paint film is not directly proportional to the thickness of the film. The curve expressing the relation of thickness of film and hiding power is of hyperbolic or logarithmic form. In the case of white and tinted paints, the first coat is very

much more effective than the second coat, and the efficiency of succeeding coats decreases rapidly. It is important, therefore, to use a pigment of high intrinsic opacity so as to secure maximum hiding in the first coat. An aluminum paint with varnish base was applied over a black iron panel; with one coat the reflectivity of the surface was 69 per cent, and with two coats the reflectivity was 70 per cent; substantially maximum reflectivity was obtained with one coat. A standard white lead-zinc oxide paint applied in the same way over the iron panel gave a reflectivity of 60 per cent in one coat and 66 per cent in two coats. Similarly, titanox paint with somewhat greater hiding power gave a reflectivity of 70 per cent in one coat and 75 per cent in two coats. When applied to dark surfaces, much thicker films of white paint must be applied to overcome the inferior hiding properties of the white paint and develop its maximum reflectivity than is the case with aluminum paint. Usually three or four coats of white paint are required to approximate its maximum reflecting power.

From the theoretical standpoint the opacity of aluminum bronze powder is undoubtedly the chief factor in explaining the durability of aluminum paint. It has long been known from a practical standpoint that light is a very important factor in the deterioration of paint. More recently the great importance of ultra-violet light has been investigated. Aluminum powder is equally opaque to visible and ultra-violet light.

It is logical from this viewpoint that the adulteration of aluminum powder with material of substantial transparency, such as mica, should lower the durability of paint made with it. Experience proves this to be the case. Test panels of mild steel were painted with one and two coats of paint made with spar varnish and aluminum powder (2 pounds of powder per gallon of varnish). The powder used in three of the paints contained 10, 25 and 50 per cent, respectively, of ground mica, and one panel was painted with pure mica suspended in spar varnish. Such adulteration may be very deceptive, because substantial amounts of mica can be mixed with aluminum powder without changing its general appearance. On the weather exposure test, the 100 per cent mica panel showed rusting after a relatively short period of exposure, and all the panels containing mica began to fail before

the panel coated with pure aluminum paint; the order of failure corresponded with the mica content.

Moisture-proofing Power.

The Forest Products Laboratory at Madison, Wisconsin, has developed a quantitative method of determining the moisture-proofing efficiency of coatings on wood that has yielded some very useful results. A description of the method and some interesting observations of aluminum paint were published in their Technical Note No. 181.¹⁶

A birch panel, coated in the manner to be tested, was exposed to an atmosphere of 60 per cent humidity at room temperature for 14 days, and then to an atmosphere of approximately 95 to 100 per cent humidity for 14 days. The moisture-proofing efficiency was calculated on the amounts of moisture absorbed per unit area of surface, assigning to the uncoated wood an efficiency of 0 per cent. Some of the efficiencies measured in this way are shown in the table.

TABLE 3.

MOISTURE RESISTANCE OF VARIOUS COATINGS ACCORDING TO FOREST PRODUCTS LABORATORY.

Coatings	Number of Coats	Moisture-proofing Efficiency Per cent
Asphalt paint	3	96
Aluminum bronze (quick drying).....	3	92
Graphite paint	3	61
Spar varnish	3	60
White lead in oil.....	3	54
Linseed oil applied hot and wax.....	5) 2}	38
No coating	0	00

Data from a later series of tests were shown graphically in a leaflet entitled "Forest Products Research in Pictures, No. 71, Moisture Resistance of Coatings for Wood." The report indicated the moisture-proofing efficiencies for the respective coatings shown in Table 4.

Additional tests have been made by the Research Bureau of

¹⁶ See also Dunlap, Ind. Eng. Chem., Vol. 18, p. 1230, 1926.

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TABLE 4.

MOISTURE RESISTANCE OF VARIOUS COATINGS TAKEN FROM "FOREST PRODUCTS RESEARCH IN PICTURES, No. 71."

Coatings	Moisture-proofing Efficiency Per cent
Aluminum leaf process, asphalt paint base.....	98
Pitch paint plus aluminum powder.....	98
Spar varnish plus aluminum powder.....	94
Bronzing liquid plus aluminum powder.....	93
Asphalt paint	90
Spar varnish	57
Linseed oil	17
Bronzing liquid	11

TABLE 5.

MOISTURE RESISTANCE OF COATINGS.

Research Bureau—Aluminum Company of America.

Coatings	Efficiency 2 coats	Efficiency 3 coats
Aluminum Paint made with Spar Varnish No. 1	94%	96%
Aluminum Paint made with Spar Varnish No. 2	92%	93%
Aluminum Paint made with Spar Varnish No. 3	86%	91%
Spar Varnish No. 1 alone.....		63%
Birch Panel uncoated.....	00	00

Aluminum Company of America, using the Forest Products Laboratory's method with the results shown in Table 5.

The specific action of the aluminum flakes is to be observed in that, although Varnish No. 1 (Table 5) had an efficiency of only 63 per cent, the aluminum paint made from it had an efficiency of 96 per cent. The bronzing liquid of Table 4 had a moisture-proofing efficiency of only 11 per cent, whereas the aluminum paint made with it had an efficiency of 93 per cent. Upon exposure to the weather for a period of six weeks, the moisture-proofing efficiency of the aluminum paints made with the three varnishes shown in Table 5 increased to 98, 96 and 96 per cent, respectively.

Prevention of "Bleeding."

Painting over oil stains, bituminous paints and other colored oil-soluble coatings presents the problem of preventing "bleeding" through, as it is called, of the ground coats. Frequently, for

MOISTURE RESISTANCE OF COATINGS

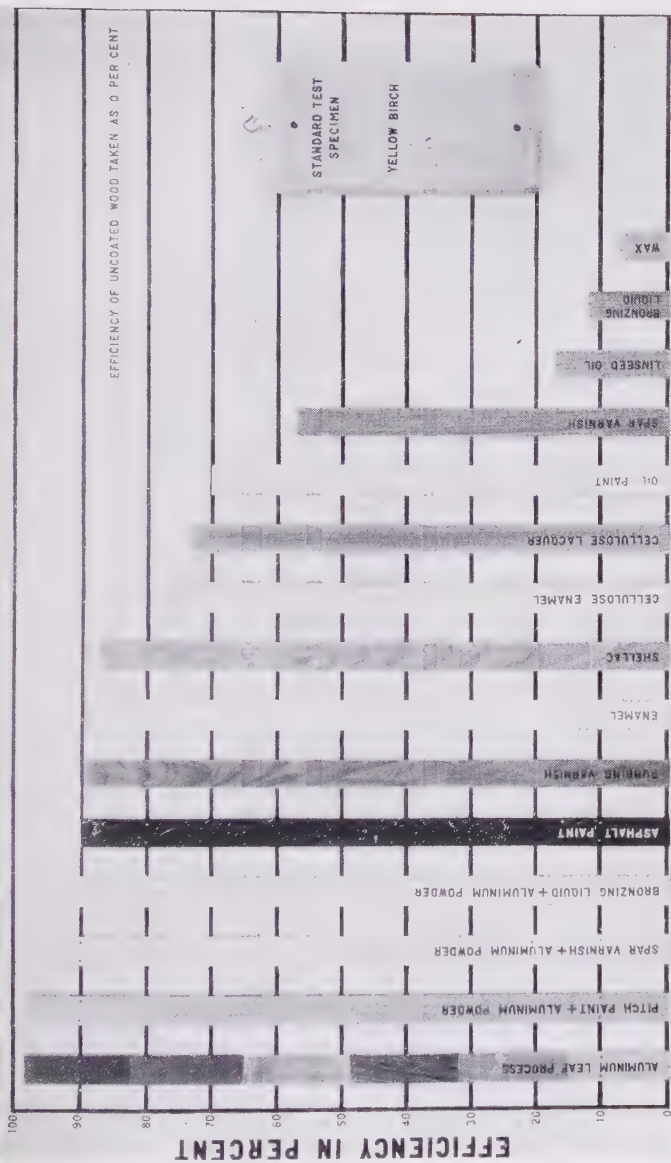


FIG. 11.—Moisture-resistance of Coatings for Wood. (Reproduced by courtesy of Forest Products Laboratory.)

example, the occasion arises for refinishing mahogany-stained woodwork in white or light colored enamel. If the enamel is applied directly, the oil stain will gradually dissolve in it and work through and stain the surface. A ground coat of aluminum paint over the stain will prevent the bleeding through and top coats of white paint or enamel may be applied on top of the aluminum with perfect safety.

Another such case is painting over bituminous paints, and here also aluminum paint can be applied satisfactorily. With ordinary light colored paints, the bituminous material is almost certain to dissolve and stain the surface. The high impermeability of aluminum paint films, as shown by the moisture-resistance test, seems to be operative against stains and the like. However, not all cases are alike, and certain guiding principles should be followed in selecting the aluminum paint. In general, the softer the bituminous coating or the more penetrating the stain, the quicker drying should be the aluminum paint vehicle and the more impervious the film it produces. Linseed oil, for example, which forms a slow drying and soft film, is usually unsatisfactory as a vehicle for aluminum paint where prevention of bleeding is desired. However, even linseed oil will function in some cases where the bituminous paint has hardened well or perhaps aged for some time. Varnishes, on the other hand, will dry faster with less softening of the undercoats and are themselves less readily penetrated. With the addition of aluminum powder, the sealing effect is almost always complete.

Five of the most commonly used bituminous paints were painted on sheet iron and allowed to dry for 14 days. They were then given top coats of aluminum paint made with spar varnish, gloss oil and bodied linseed oil as vehicles. The spar varnish was entirely satisfactory, but some staining occurred with the gloss oil, and still more with the bodied linseed oil. Similar panels were then placed on a steam-heated radiator for several weeks. This is a severe test, because the heat tends to soften the bituminous film. Even under these conditions no bleeding occurred through the aluminum paint made with spar varnish, except in the case of one very slow-drying coal-tar paint.

The test was repeated, allowing three months' drying time for the bituminous paints before applying the top coats of aluminum

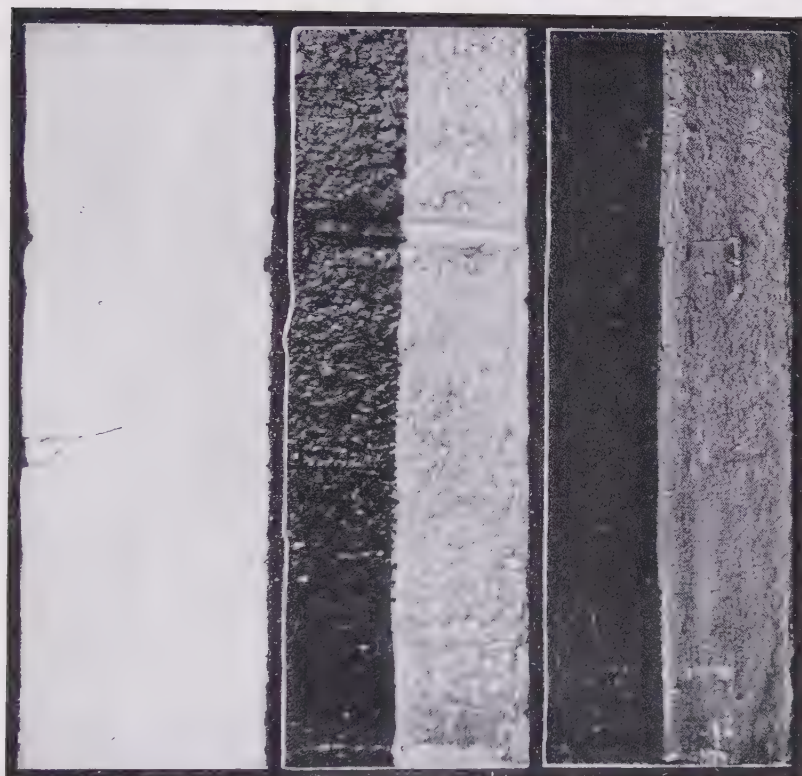
paint. The very slow drying asphalt stick paint to a slight extent bled through the aluminum paint made with gloss oil and with bodied linseed oil. Good results were obtained in all other cases.

A very important and practical use of aluminum paint is in painting refrigeration installations. One of the common insulating materials is cork-board coated with mastic or bituminous water-proofing material. Aluminum paint apparently is one of the few light colored paints which can be applied to such surfaces without staining.

In Figure 12 are shown the results of painting asphalt-coated cork board with various primers which have been recommended for the purpose. The panels from left to right were primed with aluminum paint (varnish base), red lead paint and zinc dust-zinc oxide paint. The right half of each panel was then given a coat of white lead-zinc oxide paint. The aluminum primer prevented any bleeding whatever of the asphalt; moreover, the one coat of aluminum paint gave about as bright a surface as the aluminum paint with a top coat of white. The red lead was somewhat less satisfactory as a primer, and the zinc dust primer permitted a very objectionable staining of the top coat of white by the asphalt. A quick drying spar varnish should be used as vehicle. The aluminum paint is also resistant to ammonia fumes and is a good all-round protective paint. The thermal properties of aluminum paint may also be used to advantage on insulating coatings.

Electrical Conductivity.

It might be considered, since aluminum itself is such a good conductor of electricity, that aluminum bronze powder would be electrically conducting. The presence, however, of the film of polishing agent on each particle, as well as a film of oxide, quite efficiently insulates the powder. A column of aluminum bronze powder about 2 mm in thickness and 4 mm in diameter was found to have a resistance greater than 10,000,000 ohms. Aluminum paint, therefore, with the additional insulation afforded by the vehicle, may be considered as non-conducting under some conditions. However, at some voltages—say above 100 to 300 volts—the paint film may break down and permit the current to pass by disruptive discharge. For this reason aluminum paint should not be put on surfaces which are supposed to be insulating



Panel No. 1.

Entire surface primed with Aluminum Paint (varnish vehicle) with 1 top coat white paint on right half.

Panel No. 2.

Entire surface primed with red lead paint with 1 top coat white paint on right half.

Panel No. 3.

Entire surface primed with zinc dust-zinc oxide paint with 1 top coat white paint on right half.

FIG. 12. Paints for Asphalt-coated Corkboard.

in character. It is likewise true that no paint should be applied to high voltage insulators.

Resistance to Sulfur Compounds.

Aluminum as a base metal is unique in its resistance to sulfur and finds many applications for that reason. To cite only one example, aluminum molds and forms are used in the rubber industry; they resist the action of sulfur and no discoloration can result from the contact of the rubber-sulfur mixture with aluminum. Paints containing lead pigments are discolored rapidly by even traces of hydrogen sulfide. Air containing less than one part per million by volume of hydrogen sulfide will discolor paper coated with lead acetate. It is a marked advantage of aluminum paint, therefore, that it is inert to hydrogen sulfide and is not discolored thereby.

By way of test, a steel panel coated with aluminum paint (varnish vehicle) was suspended above a hydrogen sulfide generator in a hood where hydrogen sulfide was being used in analytical operations. The panel was in contact with air containing very appreciable quantities of hydrogen sulfide for a period of six months. No apparent discoloration or deterioration could be detected at the end of that period.

White paints containing lead pigment or even traces of lead as an impurity will discolor under the conditions prevalent in most chemical laboratories. Under these conditions aluminum paint has given an excellent performance in practical use. It may be used on walls, ceilings and equipment. It combines good lighting efficiency with high resistance to chemical fume. A varnish vehicle should be employed which does not contain more than very small amounts of lead drier.

A quantitative comparison of the effect of hydrogen sulfide upon white paints and aluminum paint is given in Table 6. A series of sheet iron panels were given one coat each of aluminum paint and several standard white paints. After thorough drying they were suspended in a hood where hydrogen sulfide was being used in analytical operations. The reflectivity was measured after 3 days' exposure and after 12 weeks. The reflectivity of the panels with 3 days' exposure was measured without dusting off the surface in any way. The panels after 11 and 12 weeks' expo-

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sure were wiped lightly with a damp cloth to remove dust before they were measured. The initial reflectivities had run from 60 to 70 per cent; after 12 weeks' exposure one of the panels was as low as 24 per cent. Although the aluminum coated panel showed some loss in reflectivity, there was absolutely no yellowing of the paint. Rather a certain whitening of the surface had taken place, probably as the result of condensation of chemical fume. The white paints had all turned various shades of yellow to dark brown. The appearance of four of these panels is shown in Figure 13.

Since the white paints do not show good hiding in one coat, it seemed desirable to repeat the test, using both one and two-coat surfaces, as well as exposure to a much lower concentration of hydrogen sulfide. The second series (B of Table 6) was hung in the laboratory near the hood but not in it. Substantially the same comparative results were noted, but in lesser degree. The aluminum paint showed no yellowing, the gloss mill white was only slightly tinted, but the remaining white paints were considerably discolored.

A note on the use of the aluminum paint to resist attack by hydrogen sulfide was published in the section of Chemical and Metallurgical Engineering entitled "The Plant Notebook."¹⁷

"One of the large university laboratories has been having a great deal of difficulty with sulphide scale on copper dashing and cornices of the laboratory building. This situation was aggravated seriously because the hydrogen sulphide generator house was on the roof of the building. Bituminous paint is apparently ineffective but an aluminum paint has proven entirely satisfactory for elimination of the corrosion of the copper roofing parts.

This development indicates that many plant corrosion problems where sulphides are a serious factor may be helped materially by aluminum paint."

In many of the oil fields now being developed, corrosion of steel by hydrogen sulfide and other sulfur-containing substances is a serious problem. Furthermore, in these locations, it is difficult to protect metal with paint, since most paints are seriously affected by hydrogen sulfide. Not only does aluminum paint hold its color

¹⁷ Chem. and Met., Vol. 33, p. 498, 1926.



Panel No. 1.
Aluminum Paint.

Panel No. 2.
Gloss Mill White.

Panel No. 3.
Titanox-zinc oxide
paint.

Panel No. 4.
Lithopone zinc oxide-
inert, 40-40-20 formula.

FIG. 13. Effect of Hydrogen Sulfide upon White Paint and Aluminum Paint; one coat of paint exposed to strong concentration of hydrogen sulfide for 12 weeks.



TABLE 6.

EFFECT OF HYDROGEN SULFIDE UPON REFLECTIVITY OF WHITE PAINTS AND ALUMINUM PAINT.

A—Black iron panels suspended vertically over hydrogen sulfide generator in laboratory hood.

Panel No.	No. of Coats	Description of Paint	Per cent Reflectivity		
			Initial	After 3 days' Exposure	After 12 weeks' Exposure
1	1	Aluminum Paint with varnish vehicle	69	55	60
2	1	Gloss Mill White.....	68	45	39
3	1	Flat Mill White.....	59	39	30
4	1	White Lead-Zinc Oxide-inert, 55-35-10 formula	60	36	24
5	1	Titanox-Zinc Oxide	70	46	32
6	1	Lithopone-Zinc Oxide-inert, 40-40-20 formula	70	45	34

B—Black iron panels suspended in chemical laboratory, near but outside ventilated hood containing hydrogen sulfide generator.

Panel No.	No. of Coats	Description of Paint	Per cent Reflectivity	
			Initial	After 11 weeks' Exposure
7	1	Aluminum Paint with Spar Varnish	69	58
	2	“ “ “ “ “ “	70	58
8	1	Gloss Mill White.....	68	63
	2	“ “ “ “ “ “	70	61
9	1	Flat Mill White.....	59	50
	2	“ “ “ “ “ “	68	49
10	1	White Lead-Zinc Oxide-inert, 55-35-10 formula	60	46
	2	White Lead-Zinc Oxide-inert, 55-35-10 formula	66	50
11	1	Titanox-Zinc Oxide.....	70	56
	2	“ “ “ “ “ “	75	52
12	1	Lithopone-Zinc Oxide-inert, 40-40-20 formula	70	52
	2	Lithopone-Zinc Oxide-inert, 40-40-20 formula	74	52

in the presence of hydrogen sulfide, but if made with the proper kind of varnish, the paint itself will prove durable and render good protection to most surfaces coated with it. However, an oil base aluminum paint may not withstand some special conditions such

as the combined attack of oil and hydrogen sulfide as met with in tank interiors for example.

Tinting Aluminum Paint.

Tinting aluminum paint presents some unusual difficulties and some special opportunities for unusual effects. Aluminum bronze powder is made in only one color,—the natural one. It is true that aluminum powder can be dyed all the colors of the rainbow, but these powders are relatively expensive and the colors too fugitive to resist any extended exposure to light and weather.

The leafing of aluminum powder effectively hides substantial quantities of colored pigments added to aluminum paint. For example, up to about 3 per cent of red lead can be added to aluminum paint without any marked tinting effect. If larger quantities are added, tints are secured because of the mass effect of the pigment and because the free leafing of the powder is interfered with. If, however, the aluminum powder is allowed to stand mixed with the vehicle until leafing has practically disappeared, some very attractive metallic colors are produced. Under such conditions a uniform distribution of aluminum powder and colored pigment throughout the paint film is possible. Some unusual effects in decorating can be secured by such tinted aluminum paints, particularly in combination with stenciled patterns. The aluminum powder lends to the paint a certain silky luster which appears to give depth to the surface.

Some figures regarding the amount of pigment required to tint may be of interest. It requires about 10 per cent red oxide with 20 per cent aluminum powder, the balance vehicle, to produce a rose tint. Five per cent brown oxide, 15 per cent chrome yellow or chrome green, each with 20 per cent aluminum powder, and the balance vehicle, gave attractive light tinted paints. Ten per cent white lead with 20 per cent aluminum powder produces a paint of battleship gray color. Tinted aluminum paints show some fading on exposure. They are more durable than the colored paint without the aluminum powder, but not as durable as straight aluminum without the non-metallic pigment.

Aluminum Powder in White Paints.

The addition of small amounts of aluminum powder materially increases the opacity of white paints. This increase in opacity also

increases the durability of the white paint, as would be expected, since sunlight is such an important factor in the deterioration of white paints. In order to obtain quantitative data on this point, the transmission factor of a white paint, with and without added aluminum powder, was measured.¹⁸ The white paint employed was a commercial ready-mixed paint of the following composition:

White lead	35 per cent
Zinc oxide	22 per cent
Silica and silicates	6 per cent
Linseed oil	34 per cent
Japan drier	3 per cent

The transmission factors of paint films made with white paint alone, and after adding to it polished aluminum bronze powder in amounts of 2.5, 5, 10 and 25 per cent, were measured. The results are given in Table 7.

TABLE 7.

EFFECT OF ADDITIONS OF ALUMINUM BRONZE POWDER UPON LIGHT TRANSMISSION FACTOR OF WHITE PAINT.

Material	1st Series		2nd Series	
	1 Coat Per cent	2 Coats Per cent	1 Coat Per cent	2 Coats Per cent
White Paint	26.2	16.3	29.6	16.6
White Paint + 2.5 per cent Aluminum Powder	11.2	4.5	8.7	1.0
White Paint + 5 per cent Aluminum Powder	6.9	1.4	4.8	0.4
White Paint + 10 per cent Aluminum Powder			1.5	<0.3
White Paint + 20 per cent Aluminum Powder	3.2	0.5	1.3	<0.3
Aluminum Paint	<0.1	<0.1	<0.1	<0.1

Two series of measurements were made. Somewhat heavier coats of paint were applied in the second series and substantially lower transmission factors were obtained. The aluminum powder is enough different in color from white so that even an addition of 2.5 per cent imparts an appreciable tint to the paint. The reduction in the light transmission factor is very marked.

Panels of western yellow pine (*Pinus Ponderosa*) were painted with each of these paints and placed in the exposure racks. The

¹⁸ Edwards and Wray. "Some Special Properties of Aluminum Paint." Ind. Eng. Chem., Vol. 17, p. 639, 1925.

white paint proved to be the least durable and the aluminum paint the most durable. The durability of the white paints with added aluminum powder increased in the order of the amounts of powder added. Under the rather severe conditions of exposure at New Kensington, the addition of 2.5 per cent aluminum powder extended the life of the paint coating from about 6 to 12 months. Since it is well known that most tinted paints are more durable than pure white, a panel was prepared by tinting the white with a trace of lampblack so as to match the panel with 2.5 per cent aluminum powder as closely as possible in appearance. The improvement in durability was only about one-half as great as with the added aluminum powder.

A small amount of aluminum powder added to white paint is said to correct the "yellowing" experienced by some white paints when protected from light. Aluminum paint does not darken in the absence of light. This is a very important fact in connection with its use in interior painting and is in distinct contrast to the behavior of many white paints.

Dirt Adherence.

An important point in connection with the use of light colored paints is the ease or difficulty of keeping them clean. Some observations of Jenkins and Croll¹⁹ on the collection of dirt by painted surfaces are particularly pertinent and interesting in this connection. Contrary to the popular conception, they found experimentally that smooth, glossy surfaces collected and held more dirt than surfaces painted with a flat finish. The gloss surfaces are rich in oil and the flat surfaces rich in pigment. As the gloss of the paint film decreases, its dirt-retention power seems to decrease.

This generalization holds for both interior and exterior exposures. Of course, chalking and other factors play an important part in the ultimate result. Their experiments seem to show a specific holding power of most paint films for dirt, which decreases as the pigment concentration increases, and which is not concerned with any detectable stickiness of the surface.

It has been apparent that aluminum paint films collected less dirt than many white and light colored paints. Aluminum paint

¹⁹ Circular 219, Paint and Varnish Mfrs. Assoc. (1924).

films also wash relatively clean on exposure to rain. This is in accord with the observations of Jenkins and Croll, since a leafed aluminum paint film undoubtedly has a minimum of oil on the surface. In fact, it may be considered a metallic surface for all practical purposes. Certain it is that aluminum paint films collect a minimum of dirt and can be easily washed.

Chapter 8.

Application of Aluminum Paint.

Mixing Aluminum Paint.

The most convenient system of mixing aluminum paint is to weigh out the required amount of powder (2 pounds per gallon) and place it in the bottom of the mixing container. A portion of the measured volume of vehicle is then poured over the powder and the mixture stirred with a wooden paddle until the powder is completely wetted by the liquid. The remainder of the vehicle is then poured into the container and the whole stirred to a uniform consistency. If scales are not available, a good approximation can be made by taking 4 quarts of powder (liquid measure) to 3 gallons of vehicle. The quart measure should be filled level with powder with only a very slight tapping. A comparative test showed that it required about two minutes to measure out the ingredients and mix a gallon of aluminum paint in this way, as compared with periods of 4 to 15 minutes required by the same operator to stir up a gallon of each of various types of ready-mixed paints with non-metallic pigment so that the pigment was satisfactorily incorporated in the vehicle. In ready-mixed paints of all kinds, the pigment settles more or less to the bottom of the container. It must be thoroughly remixed with the vehicle before use if the quality and performance of the paint is not to suffer.

Ready-Mixed Aluminum Paint.

The making of a good ready-mixed aluminum paint involves a number of difficulties which only a few manufacturers have met. The loss of leafing of aluminum bronze powder upon standing in a vehicle can be controlled to a certain extent by selection of a suitable vehicle composition. Some aluminum paints will lose all tendency to leaf within a few days of mixing; others will show

substantial leafing power even after standing six months or more. Only a few of the factors involved are known sufficiently well to be controlled.

Some vehicles have a darkening effect upon the powder if allowed to stand in contact with it for an extended period. This is obviously undesirable. Other vehicles will react with the powder with the liberation of gas (hydrogen). Tests have shown that water in a vehicle will slowly liberate hydrogen on standing in contact with aluminum bronze powder. Some workers have contended that a vehicle of high acid number will cause liberation of hydrogen. The difficulty of gas generation, while occasionally met with, has not been a serious one in the development of ready-mixed paints, since it can readily be avoided by taking the proper precautions.

Under some conditions of use, loss of leafing power is not an important consideration if the color of the paint has not likewise depreciated. Leafing adds appreciably to the covering and hiding power of aluminum paint, so that more coats might be required to secure the proper results with a non-leafing paint. The best test is in practical application, and a ready-mixed paint should be examined to determine whether it has the proper spreading, covering and hiding properties, and whether the color and appearance are likewise satisfactory. Of course, the vehicle should be a durable one, especially if the paint is to withstand weathering.

Preparation of Metal Surfaces for Painting.

Almost as important as the painting itself is the preparation of the surface for painting. Paint that does not properly adhere will offer little or no protection to the surface underneath. The broadest generalization which can be made is that only a "clean" surface is in condition to be painted. Rusty, dusty and greasy surfaces are not clean from the painter's viewpoint.

Iron and steel are generally painted to protect from corrosion. If the surface is free from rust, dust and grease or any loosely adherent material, it is ready for the priming coat. Very frequently, however, it is a rusty surface which must be prepared for painting. If rust and scale are not properly removed, corrosion may continue beneath the paint film and cause eventual peeling of the paint as well as destruction of the metal. The character of the

rust will indicate the treatment necessary. If it is deep and adherent, the use of steel scraper, chisel and hammer may be required. Sand-blasting is an excellent method but is not always available. The wire brush, particularly the motordriven brush, is also effective where loose scale and rust are to be removed, but its use must be supplemented with the chisel where corrosion is deep. Mill scale, where present, should also be removed by these methods before painting. Sometimes weathering before cleaning assists in removing mill scale. While the corrosion started in this way loosens the mill scale, it is probable that the corrosion itself is detrimental to the preservation of the steel, and the practice is disapproved by many.

Where the surface has been previously painted and the paint is in sound condition, care should be taken to see that the surface is free from dust, dirt, grease and oil. Special attention is required, however, where the old paint has been applied over a rusty surface, for the paint will often be found to be scaling and peeling. All such loose paint should be carefully removed and all rusty metal cleaned as thoroughly as possible. In preparing old painted steel surfaces which have bare rusted spots, it has been found advantageous to brush coat with benzine over and around the rust spots and then burn off the benzine.²⁰ The preparation of the surface is then completed by scraping and wire brushing.

Galvanized iron, when new, may sometimes give trouble in painting because of the character of the surface, which prevents proper adhesion of the paint. A plausible explanation is that the use of sal ammoniac flux in galvanizing leaves a film of basic zinc chloride on the surface and this prevents proper adherence. One well known treatment is to wash the surface with a solution of copper sulfate or copper acetate, 8 ounces to a gallon of warm water. The solution should be allowed to dry on the surface, after which the paint can be applied without danger of peeling. Galvanized iron which has been exposed to the weather for a short time, or which has an adherent coat of paint already on it, needs no further preparation other than the removal of loose dust and dirt.

Finally, and in every case, the surface should be dry. Paint will not properly adhere to a wet or damp surface; peeling and

²⁰ Proc. Am. Soc. for Test. Mat., Vol. 21, p. 346 (1921).

blistering are the result. Freezing weather, as well as wet weather, should be avoided for exterior painting. In cold weather sufficient moisture may condense on metal to cause blistering and peeling.

Preparation of Wood for Painting.

The first consideration in painting wood is that it shall be free from grease, dirt, dust, or any loosely adherent material. In the case of wood which has been previously painted, this usually means removal of the old paint wherever it is not firmly adherent. Paint should not be applied to wet or damp surfaces. Knots, particularly in green wood, require special treatment. Brushing with turpentine or benzol and coating with shellac are two common procedures. Aluminum paint with either bodied oil or varnish vehicle is a more effective knot sealer. Tests on this point will be discussed in detail in the next chapter.

Priming Coats for Steel.

Priming coats for steel may be classified as inhibitive, neutral, or rust stimulative, depending on the effect of the pigment in retarding or stimulating the formation of rust. Basic lead chromate, sublimed blue lead, and red lead are typical pigments which rank high as rust inhibitors and which are commonly used in priming paints for iron and steel. The chromates in particular seem to exert a positive protective effect which is probably connected with the well known effect of chromates in rendering iron passive. Other pigments, like iron oxide, form durable paint films but are generally classified as neutral in their reaction towards rust formation. While aluminum is electro-negative to iron, and hence would be protective in any electrolytic reaction with iron, it is probably best to classify it with the neutral pigments. Certainly with the proper vehicle, it forms a durable protective coating on iron and steel.

In exposure tests on steel, two coats of aluminum paint have given good protection for periods of upwards of four years. Many users have also found aluminum paint to be a satisfactory primer and have employed aluminum paint for both ground and top coats. Nevertheless, there are certain conditions under which it would seem desirable to use a primer with a strongly inhibitive pigment. One such condition is where corrosion has already started in more

or less aggravated form, and where cleaning of the surface cannot be thoroughly carried out before painting. Where protection against severely corrosive conditions is desired, it is also best to use a strongly inhibitive priming coat. The priming coat should be well brushed out, so as to completely "wet" the surface and give good adherence.

Number of Coats.

One coat of any paint is inadequate protection for iron and steel or wood because of the almost unavoidable defects in the continuity of a single coat. Such defects result from brush marks, pinholes and the like. It is sound practice, therefore, to use at least two coats of aluminum paint for exterior work. The fine hiding properties of aluminum paint may give a one-coat job such an excellent appearance that a second is considered unnecessary. Experience indicates, however, that two or more coats are required for good protection. On important structures the use of at least three coats of paint is considered good practice. Also in some plant and factory structures, the interior conditions are such as to require fully as complete protection for iron and steel as if they were exposed to the weather. In building up a durable paint coating, it is essential that each coat be given ample time for drying before applying the next coat.

Priming Coats for Wood.

Aluminum paint, as will be seen from the discussion in Chapter 9, is an invaluable primer for wood. Because of the relatively large expansion and contraction of wood, a distensible paint film is necessary for durability. A bodied linseed oil (see page 32) will prove satisfactory, although a *very* long oil spar varnish may also be employed as vehicle, depending on the drying conditions which are imposed on the job. If the surface is rough, an ordinary boiled linseed oil may sometimes be employed, although aluminum paint with such a vehicle possesses definite limitations as to spreading characteristics, which have been previously mentioned.

Where a very weathered or porous wood surface is to be primed, it will usually be desirable to reduce the amount of powder to three-fourths or one-half the usual amount to allow for the extra

amount of the liquid portion of the paint which will be absorbed by the surface. Where there is a tendency for the aluminum bronze powder to dust or rub off from priming coats on wood, the difficulty can readily be corrected in this way. The obvious indication is that there is insufficient binder to hold the aluminum bronze powder together in the film because of excessive absorption by the surface. Succeeding coats of aluminum paint can carry the usual two pounds of powder per gallon of vehicle.

Painting of Brick, Plaster, Cement or Concrete Surfaces.

The first requirement in the painting of such surfaces is the removal of loose dust and plaster. If the surface has been white-washed or kalsomined at any time, it is likely to be dusty enough to prevent good adherence. In addition, there may be sufficient alkali (lime) on the surface to affect the bond. Painting such a surface is a problem and requires very careful cleaning if subsequent coats are to adhere and give satisfactory service. The surface should be thoroughly washed, followed by scraping and wire brushing, if necessary, and then allowed to slowly dry before painting.

Green plaster and cement should be allowed to thoroughly set and cure before painting. Free alkali on any surface is a hindrance to good adherence, but very small amounts can be cared for if a varnish vehicle with appreciable resistance to weak alkali is employed. The practice of washing such a surface with zinc sulfate solution (2 or 3 pounds of zinc sulfate per gallon of water), and then allowing the solution to dry on the surface, is said to be very effective.

The effect of porous cement and plaster surfaces in absorbing the vehicle is frequently very pronounced. In such cases the proportion of powder can be reduced so as to allow for the absorption of vehicle and still leave sufficient to bind the pigment to the surface. Furthermore, a relatively viscous and quick drying varnish should be employed. In these ways a paint adapted to almost any surface can be obtained. Where the surface shows marked absorption, a second coat is generally to be recommended, even on interior work. The formation of "hot spots" on plaster walls can be effectively stopped with aluminum paint.

Brushing.

In the application of aluminum paint by brush, much the same directions can be given as for non-metallic pigment paints. Aluminum paint spreads readily and smoothly. A minimum of brush work is therefore necessary to secure proper covering. The leafing of the powder helps in the leveling of the paint film and tends to eliminate brush marks and like defects. Excessive brushing is a detriment to the appearance and smoothness of the film, as there is a tendency to "ball up" the aluminum particles with long continued brushing. The most uniform appearance is obtained when the finish strokes are all made in the same direction. The paint should be kept well stirred in the container to prevent settling.

Application by Spraying.

Aluminum paint is readily applied by paint spraying apparatus. The consistency should be adjusted, if necessary, to secure proper flow, but it is no different from other paints in this respect. The paint container should be provided with agitation to maintain uniform suspension of pigment in the vehicle. The usual spray painting technique can be employed.

An important advantage in connection with the use of aluminum paint in spray equipment, as also in brushing, is the fact that the aluminum powder is non-poisonous. It is made from the same material which has proven entirely acceptable for cooking utensils. The non-poisonous character of aluminum powder is an additional recommendation for its use in countries where legislation prohibits the use of lead pigments.

Baked Coatings.

A common finish for metal articles such as apparatus, furniture, equipment, and the like, is a baked lacquer or enamel. Such finishes can be made hard and durable, are quickly applied, and dry quickly, so that they can be handled on a mass production basis. Aluminum paints and lacquers can be baked, and in fact, when the proper composition is selected, they are especially adapted for this method of application. Light colored enamels show a tendency to darken on baking, particularly if

the temperature of baking is high, as is frequently the case. On the contrary, aluminum paint, enamel or lacquer is practically immune to such darkening; this is a very important advantage. For baked finishes the vehicle most widely employed is an oleo-resinous varnish. The varnish should be one which will air-dry to a fairly hard film, and it should have a rather fluid consistency. Many of the varnishes meeting the specification on page 40 will be found satisfactory. After applying the paint, preferably by means of spraying, it can be baked at temperatures of 125° to 175° C. for periods of one-half to three hours, depending upon the temperature, the hardness of film desired, and the particular varnish employed. Several coats may be applied in this manner and no discoloration of the film of aluminum will result. It has been found that a smoother surface results thru the use of Extra Fine Varnish powder.

Certain spirit varnishes and lacquers, such as Bakelite lacquer, have also been found very effective in obtaining hard baked finishes. The time and temperature required for baking will depend upon the service required. Such a finish may be baked as high as 200° C. with safety.

Baked aluminum finishes have a bright metallic appearance, do not soil or mar easily with handling, can be readily cleaned by washing and are very durable.

Polished Aluminum Finish.

A finish resembling polished aluminum can be given an object of metal or wood by the following process: The object should first be given a priming coat of aluminum paint, which should be allowed to dry thoroughly. It should then be sanded lightly to secure a perfectly smooth surface. A top coat of clear varnish should then be applied and allowed to dry until very tacky. Baking the finish for a short time is a convenient means of reaching this stage. When just the right degree of stickiness is attained, as determined by experiment, dry aluminum bronze powder should be dusted over the surface. The surface should then be rubbed or burnished with a cloth until a smooth, mirror-like metallic finish is secured. With a little experience it is possible to produce a very effective finish. In some cases the priming coat can be omitted, if desired.

Chapter 9.

Aluminum Paint On Wood.

The application of aluminum paint to wood is an important field and requires special discussion. Laboratory and field tests have shown conclusively that it forms a durable protective coat where it is used either as a primer or top coat on wood. Of especial significance in connection with the performance of aluminum paint on wood is its high resistance to penetration by moisture. According to F. L. Browne of the Forest Products Laboratory ²¹

“Weathering is a process of mechanical disintegration. It is primarily due to the shrinking and swelling of wood with changes in moisture content. The surface layers of a shingle, board or other piece of wood alternately absorb or lose moisture rapidly if exposed to rain and sunshine or to the ever-changing humidity of the atmosphere. Changes in moisture content inside the piece, however, lag behind those in the surface layers because of the relatively slow rate of transfusion of moisture in wood. The lag tends to keep the interior at a relatively uniform moisture content and a constant volume, so that when the outside wood fibers swell and shrink they are alternately squeezed together and pulled apart. This action results in a slow breaking down and wearing away of the surface fibers, and sometimes more noticeably in ‘raising of the grain,’ checking, cracking, and splitting of the wood, and the development of a soft, flabby surface in place of the hard, abrasion-resistant surface of new wood. Weathering may be augmented by the action of frost, by the mechanical abrasion of rain, hail and wind, and perhaps by chemical changes in the wood substance brought about by the action of light, moisture and oxygen. . . . The value of paint coatings for protecting wood against weathering lies in their effec-

²¹ “The Painting Characteristics of Different Woods,” The Painters Magazine, Vol. 54, pp. 40-43, March, 1927.

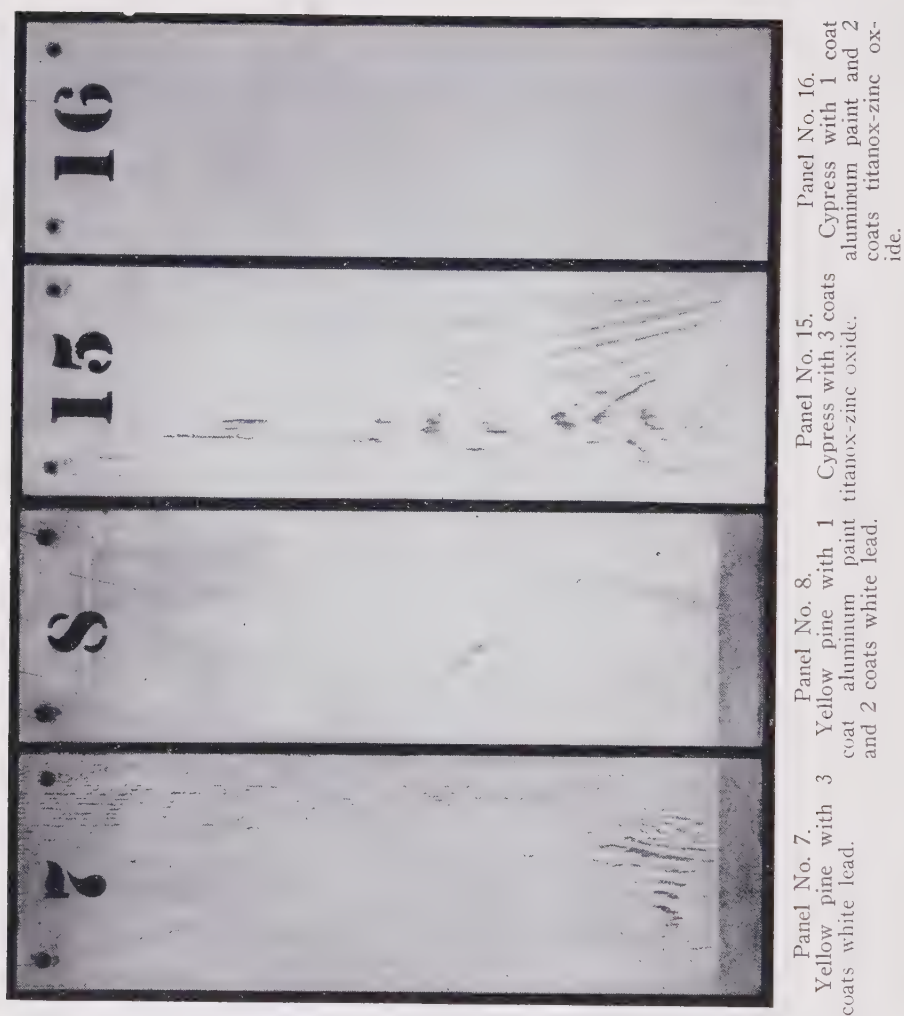


FIG. 14.—Appearance of Wood Test Panels after 12 months' exposure at Washington. (Courtesy of H. A. Gardner.)

tiveness in retarding the absorption of moisture and its subsequent drying out."

Not only is wood prevented from warping and checking by a moisture-resistant coating like aluminum paint, but conversely when the expansion and contraction of the wood is at a minimum the integrity of the paint coating is best preserved. Protected wood preserves the paint! The paint must not only have adequate initial moisture proofing power, but it must maintain it if it is to continue to protect the wood.

A comprehensive test of aluminum paint on wood was started by H. A. Gardner in January, 1924. Panels of five woods, white pine, Douglas fir, cypress, yellow pine and redwood were employed in these tests. The paints were aluminum paint made with both spar varnish and bodied linseed oil vehicles, zinc oxide-white lead, zinc oxide-titanox, white lead, and some modifications of these, notably the addition of 1.5 per cent aluminum powder to the white pigment paints. Aluminum paint was used as a primer under both the aluminum and the non-metallic pigment paints.

On the first examination of the test after twelve months' exposure, the protective action of the aluminum paint, both as top coat and primer, was readily apparent.²² The results on the first 30 test panels showed markedly better condition of paint film and wood where the aluminum primer was used than where the white paint was directly applied to the wood. This generalization held for all five kinds of wood and for the three different white paints employed. The improvement in condition as effected by the use of the aluminum primer is graphically shown in the photographs reproduced as Figures 14 and 15. In another group of panels, two types of aluminum primer were compared and sound conditions noted in nearly every case. Where white paint is applied over an aluminum priming coat, one coat of the aluminum should be sufficient. Five panels, one of each kind of wood, received three coats of aluminum paint and these were easily the best protected panels in the test; the paint films were in good condition even three years after exposure. Some improvement in the durability of the white paint was effected by the addition to it of 1½ per cent aluminum powder.

²² Circulars 199 and 231, Paint and Varnish Mfrs. Assoc. of the U. S.

78 ALUMINUM BRONZE POWDER AND PAINT

A duplicate set of panels was prepared by Mr. Gardner and exposed by the author at New Kensington. After three years' exposure, only 12 of the original 70 panels remained in the test, the others having been removed because deterioration had proceeded so far that there was no further object in continuing their exposure. The "industrial atmosphere" of New Kensington proved a severe test for these paint coatings. In Table 8 are given the data on the condition of part of these panels after two and three years' exposure.

TABLE 8.
PAINT TESTS ON VARIOUS TYPES OF WOODEN PANELS.
Exposed January 11th, 1924, at New Kensington.
Southern Exposure—45° angle.
[Key for Wood and Paint Nos. at end of table.]

Panel No.	Wood and Paint Nos.	Condition after two years
1	W-6-6-6	Moderate fine wood checking on upper half of panel; paint flaking above wood checks
2	W-1-6-6	Wood sound; moderate paint checking
3	F-6-6-6	Slight checking of wood on upper half; moderate paint checking; rosin exudations
4	F-1-6-6	Wood sound; moderate paint checking; rosin exudations
5	C-6-6-6	Many fine wood checks over entire panel; paint flaking above wood checks
6	C-1-6-6	Wood sound; moderate paint checking
7	Y-6-6-6	Wood checking very badly; paint scaling badly over entire panel
8	Y-1-6-6	Medium checking of wood; moderate paint checking
9	R-6-6-6	Wood sound; moderate paint checking
10	R-1-6-6	Wood sound; moderate paint checking
11	W-3-3-3	Wood checked badly; paint nearly all chalked off
12	W-1-3-3	Many fine wood checks; top coats completely chalked off
13	F-3-3-3	Considerable checking of wood; paint badly chalked; rosin exudations
14	F-1-3-3	Slight checking of wood; top coats practically chalked off
15	C-3-3-3	Fine surface checking of wood; paint nearly all chalked off
16	C-1-3-3	A few fine surface checks in wood; top coats of paint chalked off
17	Y-3-3-3	Wood badly checked; paint scaling and badly chalked
18	Y-1-3-3	Wood badly checked; top coats all chalked off; primer flaking
19	R-3-3-3	Slight checking of wood (edge grained); considerable chalking of paint
20	R-1-3-3	Medium checking of wood (flat grained); paint flaking and chalking

Panel No.	Wood and Paint Nos.	Condition after two years
21	W-2-2-2	Wood badly checked; paint flaking badly
22	W-1-2-2	Moderate number of fine wood checks; slight flaking of paint
23	F-2-2-2	Wood badly checked; paint flaking badly
24	F-1-2-2	Slight wood checking; moderate paint checking
25	C-2-2-2	Moderate wood checking; paint flaking badly
26	C-1-2-2	Slight wood checking; moderate paint checking
27	Y-2-2-2	Wood very badly checked; paint nearly all scaled off
28	Y-1-2-2	Wood badly checked; paint flaking badly on summer wood
29	R-2-2-2	Wood (flat grain) very badly checked; paint flaking and checking
30	R-1-2-2	Wood (edge grain) sound; moderate checking of paint
51	W-4-4-4	Wood sound; paint sound
52	F-4-4-4	Wood sound; paint sound; rosin exudation
53	C-4-4-4	Wood sound; paint sound
54	Y-4-4-4	Wood sound; paint sound
55	R-4-4-4	Wood sound; paint sound

Panel No.	Wood and Paint Nos.	Condition after three years
9	R-6-6-6	Wood sound; considerable paint checking
10	R-1-6-6	Wood sound; considerable paint checking
26	C-1-2-2	Considerable wood checking; slight flaking of paint; considerable chalking
30	R-1-2-2	Wood sound; paint shows moderate checking; top coats entirely chalked off
51	W-4-4-4	Wood sound; paint sound
52	F-4-4-4	Wood sound; paint sound; some rosin exudation
53	C-4-4-4	Wood checking in one small area over summer wood; paint cracked at this point, otherwise sound condition
54	Y-4-4-4	One fine wood check about an inch long near top of panel, otherwise sound; paint coating sound condition.
55	R-4-4-4	Wood sound; paint sound

Key to Numbers and Letters

W—White Pine; F—Douglas Fir; C—Cypress; Y—Yellow Pine;
R—Redwood

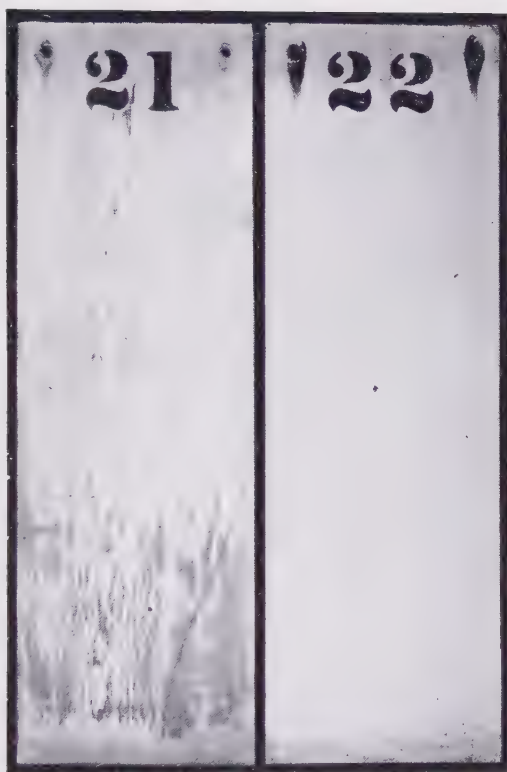
Paint No. 1—Aluminum Paint with Spar Varnish (diluted 2:1)
 “ “ 2—White Lead-Zinc Oxide Paint (50:50)
 “ “ 3—Titanox-Zinc Oxide Paint (3:2)
 “ “ 4—Aluminum Paint with Heavy Bodied Linseed Oil (diluted 3:2—Turpentine)
 “ “ 6—Basic Carbonate White Lead Paint

Example: Panel W-1-6-6 is a white pine panel with a priming coat of Aluminum Paint No. 1 and two top coats of White Lead Paint No. 6.

In these tests, as well as with the Washington exposure tests, one point stood out above everything else. The five panels (51 to 55), which received three coats of aluminum paint made with heavy bodied linseed oil, showed no signs of wood weathering after 2 years' exposure, and the paint films themselves were in sound condition, without any sign of checking or chalking. Even after 3 years' exposure their condition was excellent. The performance of the aluminum paint on the yellow pine was particularly noteworthy. No other paint combination gave adequate protection to the yellow pine. After 3 years' exposure, the protection of the yellow pine was almost perfect, there being but one very fine wood check on the panel, with the paint still in good condition.

The next point is that the panels having an aluminum primer with two top coats of white were, in general, better protected than similar panels having three coats of white. There were 15 pairs of panels with and without the aluminum primer, and in 12 out of 15 cases the aluminum primer was distinctly helpful in protecting the wood. In two cases there wasn't any choice, and in one (19 and 20), the panel with the aluminum primer was distinctly worse, although the difference in the grain of wood could readily explain this.

It is interesting to correlate these exposure tests with the moisture-proofing power of the coatings. In Table 9 are given a series of measurements made according to the method of the Forest Products Laboratory, as described on page 57. The panels with three coats of aluminum paint showed the highest moisture-proofing power (90 per cent), and in the exposure test they best preserved the wood and were themselves in the best condition. Next in order of efficiency was the combination of a priming coat of aluminum paint with 2 top coats of white. These paint coatings were less durable than the 3-coat aluminum paint films, but they were substantially more durable and gave more protection than 3 coats of either of the white paints. Another metallic paint with zinc dust-zinc oxide was tested, but the results did not indicate any appreciable improvement in moisture-proofing efficiency as a result of its use. Red lead was also ineffective in increasing the moisture-proofing power of the coating. While under some conditions too great impermeability may even be a disadvantage in a paint coating, nevertheless experience to date indicates that coatings with



Panel No. 21.
White pine with 3
coats white lead-zinc
oxide.

Panel No. 22.
White pine with 1
coat aluminum paint
and 2 coats white lead-
zinc oxide.

FIG. 15.—Appearance of Wood Test Panels after 12 months' exposure at Washington. (Courtesy of H. A. Gardner.)

as high moisture proofing power as shown by aluminum paint can be very effective and serviceable.

TABLE 9.
MOISTURE-PROOFING EFFICIENCY OF VARIOUS PAINTS.

Panel No.	Description of Coating	Moisture-Proofing Efficiency Per cent		
		1st Series	2nd Series	Average
1	3 coats of Aluminum Paint	89	90	90
2	1 coat Aluminum Paint, 2 coats White Paint No. 1	79	90	85
3	1 coat Aluminum Paint, 2 coats White Paint No. 2	89	81	85
4	1 coat Aluminum Paint, 2 coats White Paint No. 3	90	82	86
5	1 coat Zinc Dust Paint, 2 coats White Paint No. 1	80	79	80
6	1 coat Zinc Dust Paint, 2 coats White Paint No. 3	79	82	80
7	1 coat Red Lead, 2 coats White Paint No. 1	69	76	72
8	1 coat Red Lead, 2 coats White Paint No. 3	76	75	76
9	3 coats White Paint No. 1	79	72	76
10	3 coats White Paint No. 3	79	83	81
11	Birch Panel without coating	0	0	0
12	Birch Panel without coating	0	0	0

Formulas of Paints Used

Aluminum Paint	Standard Varnish Aluminum Powder.....	21%	79%
	Kettle Bodied Linseed Oil.....	60%	
	Mineral Spirits and Drier.....	40%	
Zinc Dust Paint	Zinc Oxide	20%	79%
	Zinc Dust	80%	
	Boiled Linseed Oil.....	82%	21%
	Mineral Spirits and Drier.....	18%	
Red Lead Paint	Dry Red Lead [95% Pb ₃ O ₄].....	79%	21%
	Raw and Boiled Linseed Oil.....	94%	
	Turpentine	6%	

White Paint No. 1—white lead, zinc oxide inert paint—"55-35-10" formula

White Paint No. 2—titanium oxide, zinc oxide paint

White Paint No. 3—lithopone, zinc oxide, inert—"40-40-20" formula

These white paints were commercial paints purchased on the open market.

For comparison with the moisture-proofing efficiencies of the paint coatings when new, a series of measurements was made on coatings which had been exposed for 18 months. These test pieces were cut from large panels and the backs and edges were protected

by coating with aluminum foil which has a moisture-proofing efficiency of approximately 100 per cent. In this way the efficiency of the exposed face only was measured. The aluminum paint proved to have maintained a high moisture-proofing efficiency. The efficiency of the aluminum paint made with kettle bodied linseed oil was about 70 per cent, and of the aluminum paint made with varnish base was about 80 per cent. These paint films were in sound condition and the wood showed no signs of checking. The white paint showed a moisture-proofing efficiency of only 10 to 20 per cent, and the wood was checking with some flaking of the paint above the wood checks. The correspondence between moisture-proofing power and wood protection is very striking. The complete data are shown in Table 10.

TABLE 10.
MOISTURE-PROOFING EFFICIENCY OF ALUMINUM AND WHITE PAINTS AFTER
18 MONTHS OUTDOORS AT NEW KENSINGTON.
Southern Exposure—45° Position.

Panel No.	Description of Coating (2 coats on Western Yellow Pine)	Moisture- Proofing Efficiency Per cent
1	Aluminum Paint made with Kettle Bodied Linseed Oil	70
2	Same Coating as on Panel No. 1	71
3	Same Coating as on Panel No. 1	71
4	Same Coating as on Panel No. 1	57
5	Aluminum Paint made with Long Oil Varnish	83
6	Same Coating as on Panel No. 5	81
7	White Lead-Zinc Oxide Paint (55-35-10 formula)	11
8	Same Coating as on Panel No. 7	8
9	Same Coating as on Panel No. 7	24
10	Same Coating as on Panel No. 7	16
11	Bare	00
12	Entirely coated with Aluminum Foil	100

Moisture-proofing efficiency of front faces only of above panels tested; the backs and sides were coated with aluminum foil and spirit varnish base in a similar manner to Forest Products Laboratory's "Aluminum Leaf Process." The same paint film will apparently have a lower efficiency on Western yellow pine than on birch because of the lower moisture absorptive capacity of the pine.

Painting Knots.

Difficulty is commonly experienced in painting over knots and sappy streaks in wood. The resin in the knot may gradually dissolve in the paint film and stain it, particularly if the paint

is a light colored one. Under some conditions, resin may exude through the paint film. Peeling and scaling of the paint applied over knots is also of frequent occurrence. The character of the wood and the extent to which it is seasoned are important factors in the occurrence of this difficulty. The more resinous woods, such as Douglas fir, yellow pine, or Western yellow pine, give the most difficulty.

There seems to be no sovereign remedy for knots. The commonest procedure is painting the knots with shellac. Another method recommended is brushing the knots with turpentine or benzol before painting. Aluminum paint has been tried and recommended as a knot sealer. Because of the marked impermeability of aluminum paint as shown by the moisture-resistance tests, it appeared probable that aluminum paint should be good for this purpose, and accordingly a series of coatings were tested out. The panels were Western yellow pine, especially selected to contain as many knots as possible, and each coating was tested over from 2 to 6 knots. Statistically, this is not a large number, but the results are at least interesting and correspond well with other experience.

Groups of knots treated in each of several ways were then given a top coat of aluminum paint in one series, and a top coat of white paint in another series. Aluminum paints made with either varnish or bodied oil and applied directly over the knot gave the best results in every case. The next best coatings were aluminum paint made with shellac as vehicle and shellac alone without aluminum powder. Coatings of aluminum bronze powder in gloss oil and pyroxylin lacquer gave results inferior to the tests in which no coating was applied over the knot other than the top coat; apparently in these cases the vehicle was too brittle and did not give proper adherence to the wood. Where wood is given a priming coat of aluminum paint, no other special treatment of knots would seem to be required. While this treatment is the best the author has found, it is not one hundred per cent perfect. In the case of certain of the Douglas fir panels (Table 8) exposed at New Kensington, streaks of resin exuded even through the aluminum paint, so that any statement regarding the sealing properties of a paint against resin should be tempered with conservatism.

Prevention of Staining of Redwood and Cedar.

It seems that many complaints have been made of the appearance of brown stains on white or light tinted paints applied over red cedar and redwood. Gardner ²³ has investigated the occurrence and prevention of such stains. The stain, it appears, is caused by water-soluble coloring matter found in the wood. Contact with alkaline water was found to bring out the brown spots in very pronounced fashion. The tests indicated that when red cedar or redwood is properly dried before painting, the occurrence of this staining is unlikely, but if the moisture content is high, the staining is very objectionable. The tests demonstrated that aluminum paint used as a primer on cedar and redwood effectively prevented any staining, and its use was recommended for this purpose.

Painting Patterns.

Aluminum paint can be advantageously used in protecting wood patterns. A good coating for patterns should have high waterproofing efficiency in order to minimize changes in the moisture content of the wood. Aluminum paint has high waterproofing efficiency, and has proved effective in preventing warping and checking of wood, as well as change of dimension from expansion and contraction.²⁴

A suitable method is first to give the pattern a priming coat of shellac and then sandpaper lightly to give a smooth surface for subsequent coats. Two coats of aluminum paint are then applied, using shellac as the vehicle mixed with aluminum bronze powder in the proportion of 2 pounds per gallon of shellac. The use of shellac as vehicle is advantageous because of its quick drying properties, and furthermore, its use in coating patterns is quite well established.

Two coats of orange shellac, according to tests, have a waterproofing efficiency of 13.5 per cent, while two coats of shellac with aluminum powder incorporated have an efficiency of 73 per cent. Three coats of orange shellac, with and without aluminum powder, added, showed efficiencies of 95.7 and 70.5 per cent, respectively. Long standing of the powder in the vehicle may result in some

²³ Circular 222, Paint and Varnish Mfrs. Association of the U. S.

²⁴ Protecting Patterns with Paints. Edwards and Wray, *Iron Age*, Vol. 116, p. 1588, 1925.

deterioration of the paint, so that best results will be obtained by making the paint as needed.

Experience has shown that less time need be spent in smoothing up and sanding the pattern, since aluminum paint gives a smoother coat to start with than the use of shellac alone. The use of aluminum paint on patterns is both a time and money saver. Patterns which are to be used frequently will require 5 to 7 coats of shellac, but can be even more satisfactorily protected with two coats of aluminum paint. In a practical test, two patterns were mounted on the same pattern board for use in a molding machine. One pattern was given one coat of shellac and two coats of aluminum paint made with shellac. After making 576 molds the patterns were examined. Although they had both experienced the same usage, the one coated with shellac only was worn very thin and required refinishing. The pattern with aluminum paint seemed to be in just about as good condition as when first used. The economy is obvious.

Another appreciable advantage of aluminum paint is the ease with which the patterns may be withdrawn from the mold. The aluminum painted pattern has a rather "slick" surface to which the sand will not adhere. There is thus actually effected a saving in time and labor, since less repairing of the mold is required and less cleaning of the pattern.

Chapter 10.

Aluminum Bronze Powder in the Arts.

A major part of this monograph has been devoted to the use of aluminum bronze powder in paint because of the widespread interest in the subject. Aluminum bronze powder also has important uses in other arts, such as in printing, coating of balloon fabrics, the manufacture of fireworks, and aerated concrete, to mention only some of the most important applications. Aluminum bronze powder, in addition to its obvious uses as a pigment, can enter into certain chemical reactions which have very interesting applications. An example is the well known "sparkler," which is so much in evidence on July 4th.

Aluminum Bronze Powder in the Printing Art.

The simplest method of applying bronze powders is to print the design in ink or size and then dust the bronze powder over the surface. The metallic powder adheres to the inked areas and gives a bright metallic surface; the excess powder is dusted off. The powder can be applied by means of a wad of absorbent cotton, dipped in the powder and then tapped lightly against the inked area. The sheets are next stacked until the ink has set. The excess powder can then be dusted and rubbed off with a clean piece of cotton.

The characteristics of the ink or size will be determined in part by the character of the surface to which it is to be applied. The hiding power of the aluminum bronze powder is sufficiently high so that it will generally conceal even a colored ink. Usually it is better to print with a white or unpigmented ink or size. The ink should not, of course, offset upon sheets piled against it, and should have sufficient "tack" to hold the aluminum bronze powder when it is dusted lightly against it.

Special grades of powder, known as Litho powder, are made for bronzing; they have a minimum of polishing agent on the

surface so that they will not stain or adhere to any portion of the paper not inked. The grade of powder used will depend on the effect desired. Extra Brilliant Litho powder contains some relatively large aluminum flakes which give a marked luster and brilliance to the powder. However, the finer grades give a much smoother appearing film.

The paper selected for bronzing should preferably have a surface of such character that it will not itself retain the bronze powder. Smoothness is the principal requirement in this respect. However, with a little care in the cleaning operation, almost any paper can be used. It is so easy to make a practical test that no further discussion of this point is necessary.

When bronzing operations are carried out on any substantial scale, suitable equipment should be provided. Automatic bronzing machines are made which operate dust collecting devices to retain the bronze powder which would otherwise be lost. They eliminate the dust nuisance, and if properly made and operated, the danger from explosions of dust and air mixtures. All metal parts should be given a good electrical ground connection. The equipment should be rigidly inspected from the safety standpoint to make certain that sparks, electrical or otherwise, cannot occur and ignite an explosive dust mixture.

Aluminum Printing Ink.

Aluminum bronze powder may also be used as a pigment in printing inks.²⁵ It requires somewhat different handling than non-metallic pigments in order to give the best effect. Printing inks, as a class, are quite similar to paints and varnishes in their make-up. However, they must have their consistency and drying time adapted to the special conditions of printing. Linseed oil is perhaps the most important constituent of the better grade inks. It is bodied and made into a varnish-like liquid by heating in kettles, just as previously described for paint vehicles. Other ingredients, such as gums, rosin, rosin oil, and the like may be incorporated, depending on the kind of ink which is being made. Metallic driers of the lead, manganese and

²⁵ The author is indebted to Mr. Edward Sutton of the National Printing Company of Pittsburgh, who made available the results of many experiments on printing with aluminum ink.

cobalt type are incorporated in the finished ink, together with the desired color or pigment.

A straight bodied linseed oil varnish makes a good base for aluminum ink. Some manufacturers consider tung oil to be an important ingredient of a metallic ink. The aluminum bronze powder is mixed with the base by means of a knife or spatula, and is not ground in the ink as are the non-metallic pigments. As in the case of paints, the brightest ink is secured by mixing as needed. Some darkening is usually experienced if the ink stands for very long after being mixed. Another difficulty sometimes met with is excessive thickening or solidification of the mixed ink on long standing.

The amount of powder to be added will depend upon the kind of press it is to be used on and the consistency of the base. It will generally amount to about 40 per cent of the ink by weight. The consistency of the base is an important factor—the thinner the varnish, the more powder it will carry. The consistency of the ink is in turn determined by the kind of press with which it is to be applied and the kind of paper on which it is to be printed.

On one particular job which was being run on a cylinder press, only 30 to 40 per cent of powder was used when the aluminum ink was applied over a sized impression, and about 20 per cent of powder when the aluminum ink was applied over two size coats.

With regard to the press, the suggestion may be made that aluminum ink be transferred from fountain to type with a minimum of rolling and transferring. Excessive working on plate and roll may cause some balling up of the powder. This is in contrast to the non-metallic inks, where every effort is made to spread them out to a very thin film. For this reason more care is necessary in using aluminum ink on a cylinder press than on a job press. More powder can be used in job press ink and it is easier, in general, to secure a bright metallic impression with a job press than with a cylinder press.

Standard, Extra Fine and Superior Lining powders are the grades of aluminum bronze powder most used for metallic inks. Because of the very thin film of ink employed, the coarser grades of powder do not hide and cover properly.

The paper to be printed will determine many of the details of printing. The easiest paper on which to apply aluminum ink is a

ALUMINUM PAINT

*The "Coat of Metal"
Protection*

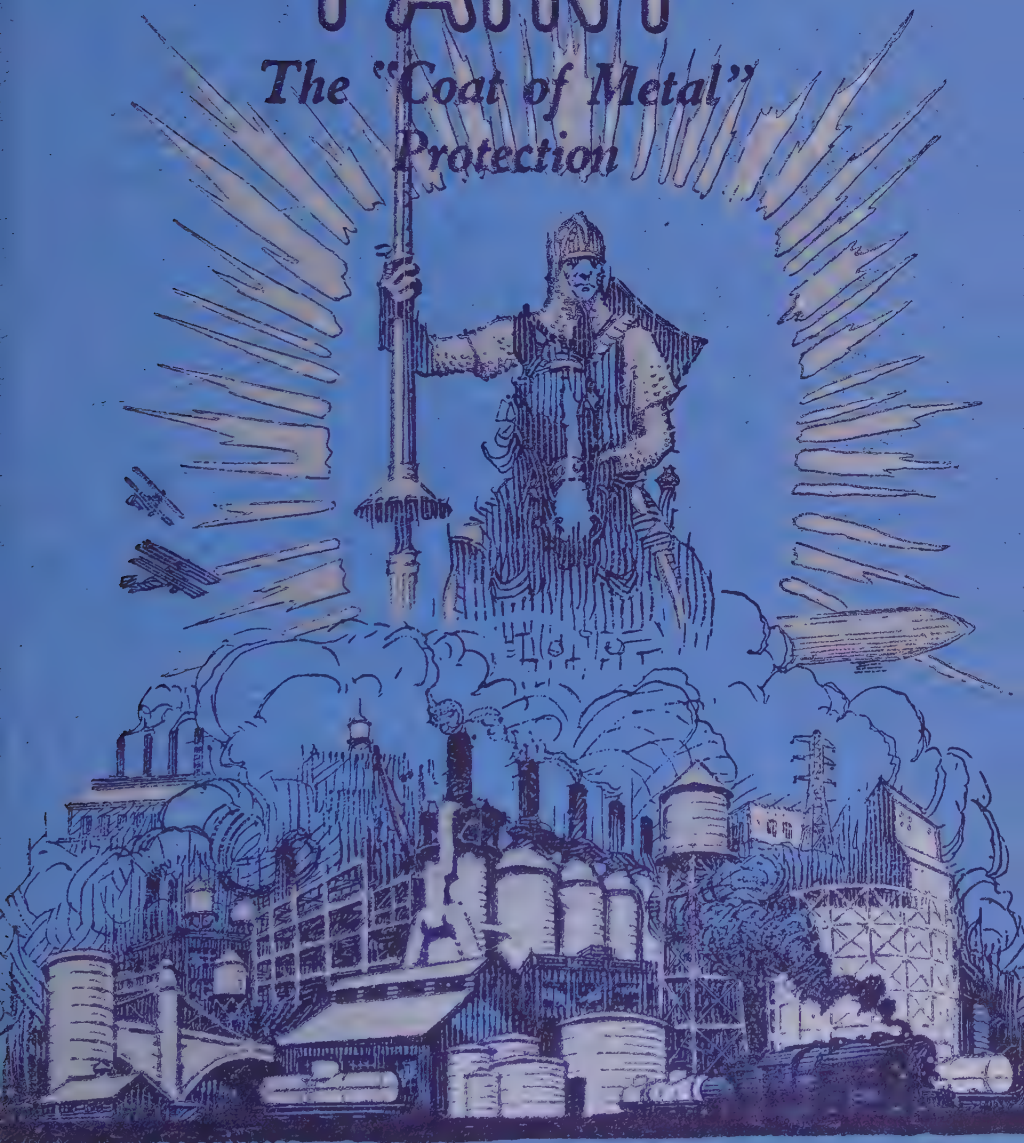


FIG. 16.—Example Suggesting Possibilities in Use of
Aluminum Ink on Colored Cover Stock.

white coated paper with a smooth, glossy surface. Even though there be relatively large areas of white paper showing through between the aluminum flakes of the ink, it does not detract from the brilliance of the printed areas because of the intrinsically high reflectivity of the white paper. In fact, it may be said that as long as the spaces uncovered by aluminum flakes are not large enough to be visibly detected, they do not interfere with the brightness and metallic effect of the printed impression.

A somewhat different situation prevails where the ink is printed on a colored coated paper. If good covering is not secured, the paper may show through and give the impression a tinted effect. Nevertheless, the smooth coated surface, even if it is colored, takes aluminum ink so well that it is seldom necessary to give it a preliminary printing with size.

The problem of applying aluminum ink effectively becomes more complicated as the surface and texture of the paper becomes rougher and more open. With papers having a plated finish, it is generally desirable to print first with size. On colored paper the size coat is more effective if it contains some white pigment. A mixture of 1 part of white ink to 2 parts of size has been found to work well. A very small amount of aluminum bronze powder can be added to the size coat. However, if too much powder is added the ink is likely to offset against the sheets piled on it. When the size coat has set to just the right degree of tackiness, the top impression of aluminum ink can be applied. The white pigment in the size probably helps to conceal the colored surface, but the principal function of the size coat is to give a smooth flat surface for the aluminum ink. It is still more of a problem to apply aluminum ink to papers having what is known as antique finish. On these it may be necessary to use two size coats. The first impression may contain a little white pigment, and should be allowed 24 hours to dry before applying the second coat. The second coat of size can be applied without pigment, and after setting 2 or 3 hours to become tacky, the top impression of aluminum can be printed.

Aluminum ink will not give the best results on bond paper without a preliminary coat of size. With the size coat, excellent results are attainable.

The setting and drying of the aluminum ink impression can be

improved and hastened by passing the printed sheet over a series of gas flames arranged to just touch the paper in passing. The tendency to offset is reduced in this way.

In printing wall paper, distemper or water colors are commonly used. The adhesive medium may contain starch paste, gum, and the like, mixed with water. Aluminum bronze powder can be effectively used in such a medium for decorating wall paper, but a special grade is necessary. In finishing the bronze powder, a polishing material must be employed which will permit uniform suspension and dispersion of the powder in the aqueous base without loss of color or objectionable reaction of the powder with the water.

Hot Stamping Process with Bronze Powder.

A printed or embossed impression having the appearance of burnished aluminum foil can be produced by a novel printing process requiring special equipment. In this method, known as the "roll leaf process," the aluminum bronze powder is carried on a transfer leaf. This leaf is a special glassine paper which has been coated with a thin layer of wax and then a very thin and uniform layer of bronze powder mixed with a binder and topped off with a coat of sizing material. This transfer leaf is made up into rolls and mounted in the press so that it feeds past the die. The brass die, which carries the design, is heated to a suitable temperature. At each impression the hot die presses the transfer leaf against the paper which is being stamped or embossed and the film of bronze powder is transferred to the paper. After each impression the roll leaf is automatically advanced the width of the die to bring a fresh area into position. The bronze powder film is only transferred where it is pressed by the hot die. The unused area of the film is wasted. All kinds of bronze powders and non-metallic pigments can be applied by roll leaf. A metallic aluminum impression can be produced in this way which is more brilliant and lasting than can be produced by "bronzing" or printing with aluminum ink.

Metallized Paper.

Metallized paper is made with an aluminum finish. The paper is first coated with a suitable adhesive and the aluminum bronze powder then applied in a thin and uniform film. Another method

is to mix the aluminum bronze powder and adhesive together and apply a thin film of the mixture to the paper. The process is usually made continuous by the use of paper in rolls. It may be given a smooth burnished finish by calendering and various artistic finishes are produced by embossing.

Colored Aluminum Powder.

Although aluminum metal cannot be colored by any small amount of alloying ingredient or otherwise, the aluminum flakes can be given a surface color by dyeing. In this way a series of very brilliant powders can be produced which are used for decorative purposes, sign painting, etc. In order to dye aluminum bronze powder, it is first necessary to remove any greasy substance from the surface of the flakes which has been introduced in the stamping process and leave the surface with an oxide or mordant film which will absorb enough of the dye to color it. It is then immersed in a solution of the dye, and the dye solution evaporated on the powder. Typical dyes which are used are—auramine, chrysoidine, fuchsine, rhodamine, saffranine. The dyed powders are finished by polishing in much the usual way.

Smalley ²⁶ has given many interesting details regarding the dyes used and the technique of their application. Von Schlenck ²⁷ recommends treating the powder with a 10 per cent alcohol solution of tannic acid in order to clean and mordant the surface, after which the powder is dried. The powder may also be treated with a boiling 0.5 per cent solution of alum. It is then mixed with an alcoholic solution of appropriate dye and evaporated to dryness with agitation in order to uniformly coat the flakes without their sticking together. Skill and experience are necessary to produce a satisfactory product.

The dyed powders are limited in their application by the fact that none of them are absolutely fast to sunlight; this limitation is more or less serious, depending on the particular dye employed and the conditions under which the powder is to be used. For the general class of work on which they are used, they are quite satisfactory. The colors available include crimson, cerise, gold, brown,

²⁶ *The Metal Industry* (London), Vol. 25, p. 369, 1924.

²⁷ *Metal Industry* (New York), Vol. 15, p. 299, 1917.

violet, blue, emerald green, turquoise blue, etc., in the most brilliant and attractive shades.

Aluminum Bronze Powder in Cellulose Plastics.

Certain grades of aluminum bronze Lining powders are used to obtain decorative effects in moulded cellulose plastics. These plastics, of which Pyralin is an example, are in many instances pigmented to obtain certain decorative color effects and various degrees of transparency. When aluminum bronze powder is used as a pigment for this purpose, a decidedly pleasing and novel effect is produced. With the particular method employed to introduce the powder into the plastic mass, the powder flakes in different areas assume different orientations, reflecting light beams in as many different directions. This produces what might be termed a silky appearance somewhat similar to the moire effect obtained by water processing silk. Its appearance is also suggestive of mother-of-pearl. The appearance of the article changes according to the angle at which it is viewed with the eye, each new position bringing into play light reflections from a new combination of bronze powder flakes. This effect is further enhanced by dyeing the plastic or using dyed aluminum bronze powders or both.

Metallics.

For decorative purposes a special grade of flake aluminum is made, which is sometimes referred to as "metallics." Metallics consist of coarse aluminum flakes between about 10 and 16 mesh in size. In metallizing a surface, it is coated with glue or varnish, and while the surface is tacky, the metallics are dusted on. It is a bronzing process quite similar to that used in printing.

This powder can be used in Christmas decorations to give a bright and scintillating surface, or in show window dressing.

Aluminum Powder in the Aircraft Industry.

Aluminum bronze powder is almost indispensable in the fabrication of durable balloon fabrics. The gas-retaining properties of these fabrics are given by the thin film of rubber contained between the plies. Without protection from sunlight, these thin films of rubber, about 0.1 mm, more or less, in thickness, are subject to excessively rapid deterioration. Even the cotton fabric itself suffers



FIG. 17.—Photomicrograph of Thin Cross-Section of 2-ply Balloon Fabric.

from sunlight. A top coating of aluminum bronze powder on such a fabric affords protection from sunlight with minimum increase in weight.

In Figure 17 is shown a thin cross-section of a two-ply balloon fabric, which illustrates the construction. The two plies of cloth are shown with a relatively thick gas-retaining film of rubber between them. One ply is laid on a bias of 45° ; this is shown in the illustrations by the variation in the angle at which the threads in the warp and filling of each ply are cut. On the outside is seen the thin, opaque coating of pigmented rubber which protects the rubber and fabric beneath. It is this top coating which contains the aluminum powder protection. A thin film of rubber, scarcely noticeable in the picture, is also provided on the inside surface of the fabric.

The gas-retaining film must be spread with skill and perfection, for it is very thin, frequently not over 0.1 mm thick, and yet it must be applied in twenty or more separate coats. The two-ply fabrics weigh from 9 to 12 ounces per square yard. For large airships of the dirigible type, heavier three-ply fabrics are frequently employed.

The rubber compound before application is in the form of a dough, made by kneading rubber, sulfur and other compounding materials with solvent. This dough is applied by means of a machine known as a spreader, in which the fabric is drawn between a roll and a knife which scrapes off the excess compound. For the top coats, aluminum powder is mixed with the dough. The color of aluminum bronze powder is unaffected by the sulfur employed for vulcanization, which is very fortunate. Where an extra bright coating is desired, the top coating may be lightly dusted with aluminum bronze powder.

Another method which has been used in applying the aluminum coating is to make a thin rubber cement containing the aluminum powder and print it on the fabric. In this method an engraved steel roller picks up a thin film of the aluminum-rubber compound and transfers it to the fabric.

Aside from the protection it offers, the aluminum coating is valuable for the thermal protection it gives to the gas envelope of a balloon or airship. By reflecting a large portion of the sunshine, it minimizes temperature changes. For this reason an aluminum

coating is applied even to rigid airships, where the outer envelope is not rubberized nor does it have to be gas-tight. Aluminum paint with either varnish or pyroxylin vehicles is used for the purpose. It helps preserve the fabric because of its opacity to sunlight. Similar use is made of aluminum paint on the fabric covering of airplane wings.

Pyrotechnic Uses of Aluminum Bronze Powder.

Aluminum bronze powder is used in the manufacture of sparklers and other pyrotechnic articles. The sparkler is made from a mixture of aluminum powder and a nitrate, together with steel filings. The combustion of the aluminum powder-nitrate mixture raises the steel filings to the ignition point, and they burn with a shower of bright, scintillating sparks. The sparks themselves are about as harmless as a shower of sparks from steel held against a grinding wheel. The end of the sparkler is, however, of appreciable size and at a very high temperature, and hence not to be touched with impunity.

In making sparklers, the ingredients—for example, aluminum bronze powder, steel filings, barium nitrate, and an adhesive such as dextrine—are mixed into a thick paste with water. The steel wire which is to form the base of the sparkler, is dipped into the paste and coated with it for perhaps half its length, after which it is dried on the wire. A grade of unpolished powder is used for sparkler manufacture.

Another use of unpolished aluminum bronze powder is in the manufacture of star shells and flares. The aluminum powder burns very rapidly and with a bright white light. In colored flares, the amount must be limited in order not to mask the color. The rate of combustion can also be controlled by using mixtures of aluminum bronze powder with a coarser grained aluminum or atomized aluminum.

Flashlight powders consist principally of powdered magnesium but aluminum bronze powder is frequently added to modify the actinic properties of the light and control the rate of burning of the powder mixture. The duration of flash is shortened by increasing the proportion of magnesium or decreasing the particle size.

Recovery of Gold and Silver from Cyanide Solutions.

An important chemical use of aluminum bronze powder is in the recovery of gold and silver from cyanide solutions. In the cyanide process of treating gold and silver ores, the finely pulverized ore is leached or agitated with a weak solution of sodium or potassium cyanide to dissolve the precious metals. The clear solution is then treated to precipitate and recover the gold and silver. Zinc shavings or zinc dust have been commonly used to precipitate the precious metals. Aluminum has also been successfully used. Some metallurgists much prefer aluminum, especially when the ore contains considerable arsenic, because it precipitates the gold and silver without forming cyanide compounds, and hence fouling of the solution with zinc and arsenic is avoided. Aluminum bronze powder made with a minimum of grease is being used for this purpose.

Thermit.

The so-called "thermit" reaction involves the reduction of various metallic oxides, by reaction with granular metallic aluminum. The heat of reaction between aluminum and ferric oxide, for example, is sufficient to melt the reduced iron and heat it to a relatively high temperature. The reaction is extensively employed for preparing carbon-free metals and alloys. Another far-reaching application has also been made in welding; it provides a convenient means of producing large or small quantities of clean, superheated iron, or iron alloy, at the point of the weld.

Grained aluminum, which consists of more or less spherical particles of aluminum of substantially larger volume than the flakes of aluminum bronze powder, has been generally used for the thermit mixture. However, under some conditions where it is desired to change the speed of reaction, a certain proportion of aluminum bronze powder may be incorporated in the reaction mixture. Aluminum bronze powder from 10 to 20 mesh in size is suitable for this purpose.

Aërated Concrete.

J. W. Aylsworth and F. L. Dyer²⁸ conceived the idea of making light and porous concrete by blowing it full of gas

²⁸ U. S. Patent 1,087,098. Feb. 17, 1914.

bubbles and permitting it to set or harden in this condition. For the gas bubbles, they depended on the evolution of hydrogen by the reaction of aluminum bronze powder with water and weak alkali. The process simply involves making a mixture of Portland cement, sand, or other aggregate, aluminum bronze powder and water, filling it into a mold and allowing it to expand and set. The alkali content of the Portland cement may be sufficient to cause the gas evolution to proceed at a suitable rate.

Such a process has been commercially developed and applied on a substantial scale in Europe, and a similar development is being undertaken in the United States.²⁹ According to G. V. Lang,³⁰ the outside walls of a building in Stockholm are built of 8-inch slabs of this material. A new central parcel post-office is being erected in Stockholm, using aërated concrete block for the walls. In England, also, its use on a number of large projects demonstrates widespread interest in the process and the economies which it affords.

Manufacture of Aërated Concrete.

The manufacture of aërated concrete is a relatively simple matter once the technique is developed. The principal requirement of the aluminum bronze powder is that it shall be substantially inactive when mixed with the cement before the addition of water, and after the concrete mix is made, the aluminum powder should react with the water and the free lime of the cement to produce hydrogen. The evolution of hydrogen should be gradual and yet complete, so that the mixture is uniformly expanded with small gas bubbles, which cause it to swell to about twice its usual volume and give a porous, sponge-like texture. A special grade of powder is supplied for this purpose.

When an especially light material is desired, ground cinders should be used with the cement. Sand may also be employed or mixtures of sand and cinders, as well as slag and other similar aggregate, depending on the properties desired. A typical mix consists of 10-mesh cinders and cement in the ratio of 40 to 60,

²⁹ Aerocrete Corporation of America, New York City, which has acquired the Aylsworth and Dyer patent.

³⁰ Aerocrete, a Porous Cement Used for Making Blocks in Europe. Rock Products, p. 89, May 29, 1926.

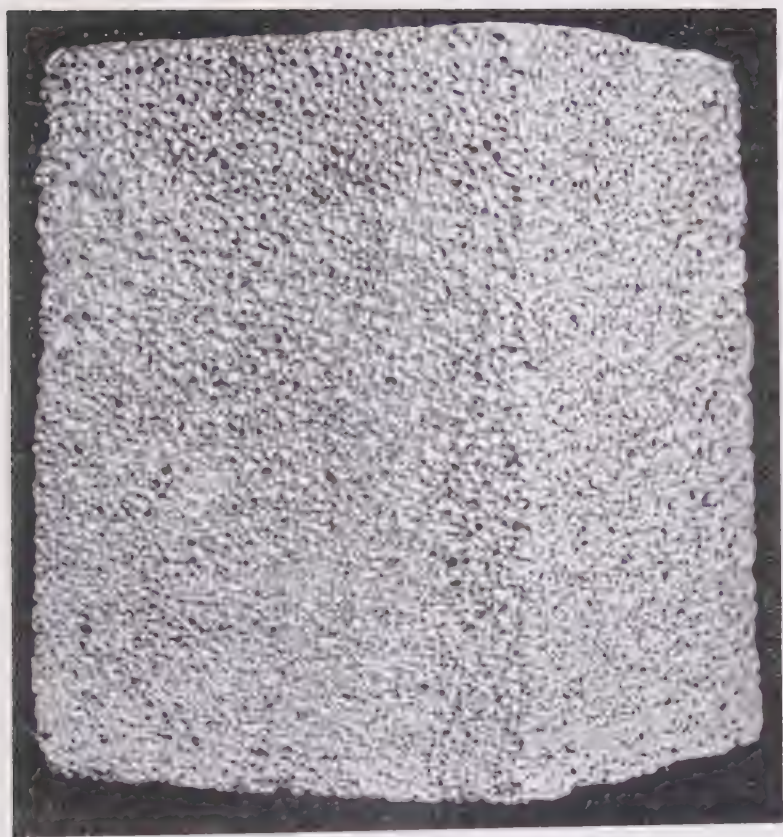


FIG. 18.—Block of Aerated Concrete.

with 0.10 per cent (1.0 pound per 1000 pounds of mix) of aluminum bronze powder. In order to accelerate the action slightly, the mix should be kept at a temperature of 85° to 95°F. The mixture should be just wet enough to flow down the trough of a concrete mixer by gravity. It can be filled into forms for making blocks, or it can be cast in slabs of various shapes and sizes. In filling forms it should be placed to a depth of only about a foot at a time in order not to interfere with the gas-expanding process. After one layer has set, another can be filled in on top. The expanded or aërated concrete is allowed to harden in the usual manner.

Properties of Aërated Concrete.

The density of aërated concrete will vary with the character of the filling material and the amount of gas expansion. The material made with cinders for building purposes should have a density of about 0.8 to 1.0. This will correspond to a weight of about 50 pounds per cubic foot, as compared with 130 pounds per cubic foot for ordinary concrete. It can be cut by saw and worked with common wood-working tools. The compressive strength, shown by various tests on material having a density of about 0.8 has ranged from 250 to 500 pounds per square inch. The strength naturally decreases as the porosity and lightness increase.

An important property of aërated concrete is its high thermal insulating value. According to tests by A. H. Barker (London University College), 8 inches of aërated concrete is equivalent in insulating value to 20.5 inches of brickwork, or 31 inches of rough concrete. By the use of aërated concrete, the same thermal insulation can be secured with much thinner walls. Walls and floors made of this material are said to be practically soundproof.

Miscellaneous Uses of Aluminum Bronze Powder.

In the preceding sections most of the major uses of aluminum bronze powder have been outlined. Other important uses and some not so important should be noted before closing. These particular uses are mentioned because they are suggestive of the wide variety of applications of this versatile product.

Some manufacturers of solid rubber truck tires incorporate aluminum bronze powder in the rubber stock next to the steel rim.

The bronze powder prevents creeping of the tire along the steel rim while in service.

Considerable quantities of aluminum bronze powder have been used in coating iron and steel ingot molds. Charles McKnight³¹ has patented a mold wash for this purpose which contains aluminum bronze powder as its essential ingredient. According to McKnight's method, a suitable mixture is made with 1 pound of aluminum bronze powder, 2 pounds of powdered graphite, and 1 pint of molasses diluted with water to a volume of 2 gallons. The wash is applied to the hot mold and when dry leaves a thin coating of aluminum and graphite on the surface. The users claim that this coating minimizes surface defects in the ingot, such as porosity, blowholes and oxide inclusions.

Aluminum bronze powder is incorporated in transparent or translucent sealing wax to give various novel color effects. It is also used in decorating wax candles.

Compounds for automatically sealing leaks in automobile radiators and water circulating systems are of many varieties. Some employ aluminum bronze powder as one of the ingredients designed to plug the leak. George I. Ray³² has patented such a mixture with aluminum powder, flaxseed meal, sulfur and soap. The flaxseed is supposed to lodge in the opening while insoluble aluminum compounds are forming to permanently heal the leak. Unfortunately, these leak-sealers sometimes clog other parts of the system than they were intended to.

A type of "drain pipe cleaner" is being marketed which consists of a mixture of dry sodium hydroxide (lye) and sodium carbonate with metallic aluminum. The mixture is shaken into a clogged drain which presumably contains water. The reaction between the aluminum and the alkali generates considerable heat and the vigorous evolution of hydrogen continually agitates the mixtures. The combined attack is supposed to discourage any obstruction. Aluminum filings and shavings are sometimes employed because of their low cost, but aluminum bronze powder has also been used for the purpose.

Aluminum bronze powder rubbed on a leather or canvas strop is said to aid in giving a fine edge to a razor. No quantitative

³¹ U. S. Patent 1,331,816, Feb. 24, 1920.

³² U. S. Patent 1,613,055, June 10, 1926.

experiments seem to have been performed in this field. However, Montgomery Waddell has gone so far as to patent a composition for rubbing on razor strops which consists of cocoa-butter and aluminum powder.²³

In the motion picture industry, aluminum bronze powder is used for coating projection screens, particularly of the portable type for home use. The powder is applied in a varnish vehicle. While on the subject of motion pictures, mention might be made of the fact that aluminum bronze powder is used by "screen" actors and actresses to simulate gray hair. Dusted lightly on the hair, the photographic effect is very realistic.

Still the list is not complete and new and interesting applications of aluminum bronze powder are constantly being developed.

²³ U. S. Patent 755,589, March 22, 1904.

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